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Emerging Energy Alternatives for the Southeastern States

Proceedings of a symposium held at
North Carolina A&T State University
Greensboro, North Carolina
March 31, 1978

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Emerging Energy Alternatives for the Southeastern States

Elias K. Stefanakos, *Editor*
North Carolina A&T State University

Proceedings of a symposium sponsored by
Department of Energy, Washington, D.C.;
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and North Carolina A&T State University,
Greensboro, North Carolina, and held at
North Carolina A&T State University
March 31, 1978

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1978

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EMERGING ENERGY ALTERNATIVES
FOR THE
SOUTHEASTERN STATES

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PREFACE

This volume contains the proceedings of the first Symposium on Emerging Energy Alternatives for the Southeastern States, held at North Carolina Agricultural and Technical State University, Greensboro, North Carolina, March 31, 1978.

At the time of the oil embargo (1973), we all became keenly aware of our extensive dependence on foreign energy sources. Since that time, many energy conferences and symposia have taken place every year throughout the United States. The majority of these conferences and symposia, however, have been very technical in content and have mainly addressed scientists and engineers already involved in research and development of energy sources. There exists a great need for a serious effort by the experts in the field of energy to inform professionals and businessmen as well as the general public about the potential of the so-called "Alternative Energy Sources" to alleviate the serious energy situation we are presently in.

The main purpose of the A & T Symposium was to try to fill this need, on a regional basis, by bringing together interested individuals and qualified experts in an open discussion of the present state and future promise of the alternative energy sources for the Southeastern States.

In general, the Symposium was a great success. About two hundred and fifty participants consisting of university students, faculty, businessmen, alternative energy equipment suppliers, housewives, etc., registered for the Symposium. During the panel discussion, the panel experts were challenged by serious questions concerning technical feasibility, cost effectiveness, environmental pollution, and short-term impact of the various energy alternatives.

We are grateful to the invited speakers for their excellent presentations. Special thanks are due to the Symposium Committee for their tremendous efforts to ensure proper representation of the various alternative energy sources. The financial support by the U.S. Department of Energy, Education Programs Division, and by NASA Langley Research Center is greatfully acknowledged. Above all, however, we express out sincere thanks to the IEEE Student Group representatives who took care of all the local arrangements and registration.

It is almost impossible to thank all of the individuals who contributed to the success of the Symposium. Sincere appreciation is extended to Dr. Winser E. Alexander (North Carolina A & T State University), Dr. David Klett (North Carolina A & T State University), Dr. Lewis C. Dowdy (North Carolina A & T State University), Dr. John Duberg (NASA Langley Research Center) Dr. Alvin Anderson (NASA Langley Research Center), Mr. Tom Pinelli (NASA Langley Research Center), Mr. Frank Meacham (S & M Equipment Corp.), Dr. Reginald Amory (U.S. Department of Energy), Dr. Richard E. Stephens (U.S. Department of Energy, Mr. Phillip Jeter (North Carolina A & T State University) and Dr. William J. Craft (North Carolina A & T State University) for their

outstanding cooperation and support. Last but not least, it is a pleasure to thank Mrs. Monica Williams for both helping with the registration of participants and typing the most difficult part of the manuscript (panel discussion), and Mrs. Karlene Stefanakos for helping with the transcript of the panel discussion tapes.

We wish to extend our gratitude to the Scientific and Technical Information Programs Division of the NASA Langley Research Center for publishing these proceedings.

Suresh Chandra
Dean, School of Engineering
North Carolina A & T State University

Elias K. Stefanakos
Symposium Chairman

WELCOME

Lewis C. Dowdy, Chancellor
North Carolina Agricultural and Technical State University

To the Presiding Officer, to our Speaker, the Honorable Robert Scott, to the other platform guests, and to all of you who have assembled here for this important Conference, please accept my immeasurable gratitude for joining us today in this our "Symposium on Emerging Energy Alternatives for the Southeastern States".

First of all, I would like to convey to each of you the appreciation of the North Carolina A & T State University Board of Trustees, Faculty and Student Body, for your participation in these important deliberations about the nation's energy supply.

We at North Carolina A & T State University have always believed that it is the duty of our University to become deeply involved in seeking solutions to the concerns of our citizens. As a bona fide Land-Grant Institution, we are extremely proud of our three-pronged mission of teaching, research, and public service.

The nation's energy supply or lack of energy supply, depending on which newspaper or magazine you elect to believe, burst upon us a few years ago and has had us in jitters ever since.

Out of all of this turmoil, we have learned one thing and that is we in America have not always been prudent stewards of the natural resources with mastery, we have wasted much and we have not often thought of conservation.

Our energy dilemma has also taught us that we can no longer afford to have our energy supply governed by other nations of the world.

Scientists tell us that we are continuously increasing our dependence on imported oil. How long can we afford to indulge that kind of strangulation? We must begin to determine our own energy future.

We must look to our natural leadership, and to conferences like this, and to researchers across the nation to continuously prod us and to suggest ways of maximizing our sources of energy.

It is going to be extremely important in the immediate future that we develop highly dependable alternative sources of energy for our nation's industries and energy for the heating of our homes, for the operation of our automobiles, our lawnmowers, and our farm equipment.

I can see by your Program that we have secured for this Conference outstanding researchers who are prepared to deal realistically with such measures as harnessing the unlimited energy of the Sun and even going back to using effectively the products of our nation's forests, that is, wood.

We are especially grateful that North Carolina A & T State University is joined in the sponsorship of this Conference by the Langley Research Center of the National Aeronautics and Space Administration and the U.S. Department of Energy, Education Programs Division.

This is an excellent example of government and higher education pooling their resources for the common good. Similar results are achieved when colleges and businesses join hands. We are confident that this nation can rise to this momentous challenge and insure an energy-sound future.

We hope this Conference will prove to be fruitful, and that you will get to know our University even better. Please let us know if we can add to your conforts while you are here.

I thank you.

KEYNOTE ADDRESS

Robert W. Scott, Federal CoChairman
Appalachian Regional Commission

In about a five-year period, energy has grown from a non-subject to the prime subject of domestic concern. Given a choice to take-it-or-leave-it as something to talk about, most of us would have been quite content to leave it. Now, however, we'll take energy from wherever we can get it, as indicated by the range of alternative sources to be discussed today.

Very properly, the discussion for today has a double focus: energy alternatives and the southeastern states. These are part of a broad set of issues and concerns, matters that provide the context for the focus of this symposium.

If we were asked to date the onset of our present day concern about energy, virtually all of us would mention the oil embargo. That event made us painfully aware of the tenuous nature of our access to a traditional energy source. However, it did not change in the slightest the overall physical availability of energy sources. I point this out because although everyone in a group may be concerned about energy, each can easily be focusing on a different aspect of the situation. I think it is possible to identify four separate concerns:

-- Present energy sources are finite and the world is simply going to run out.

-- Energy availability depends increasingly on the willingness of others to sell to us, and places us in a vulnerable political and economic situation.

-- Energy is going to get increasingly expensive, and thus jeopardizes our accustomed employments and way of life.

-- Energy acquisition and use, particularly coal and nuclear sources, can have adverse effects on human beings or the natural environment that must be precluded by public policy.

These are four different positions (although one person may hold any one or all of them) and they lead to considerably different public policies. That is the key point that all of us must bear in mind.

The first of these presumes that the supply of conventional energy sources will be exhausted before technology and science devise and make practical those alternatives that are not considered exotic. It therefore argues for strict conservation to delay the arrival of doomsday.

The second focuses on the geographic source of energy, is based upon the observed increase in U.S. dependence on imports, and argues from a foreign policy standpoint that we cannot afford the limitation on our Great Power status that our continuing dependence could produce. This position does not basically fear growing energy consumption. Its emphasis is on providing more of our energy from domestic sources.

The third position reflects a belief that we have structured our society on the basis of relatively cheap energy. As this input to our industrial and personal activities becomes relatively more expensive, considerable changes in where we live, how we work, what we sell, and how we spend our leisure can be expected, and public policy should be geared to easing these transitions.

The fourth position leads to health and environmental protection policies, including those that limit or preclude the use of some energy sources, because their development poses such a threat.

What we have, then, is a spectrum of attitudes towards energy that ranges from "energy is scarce, use it sparingly" to "some sources of energy are dangerous, don't use them at all even if other sources are scarce." In between there are prescriptions of "use domestic energy" and "smooth the way for economizing on energy use." Although some of these are inconsistent, not all of them are and we should be careful, as we consider the energy alternatives for the Southeast, to know which one or ones we believe.

As a nation, our behavior does not suggest that we truly believe that the world is running out of energy. However, our last three presidents have all urged us to be conservative in our use of foreign energy sources. We have no full-fledged program to ease the adjustment to less intensive energy uses and we certainly have great ambivalence toward two energy sources with large potential--coal and nuclear energy.

As you examine energy utilization in the Southeast, it is clear that historically the area has been a net exporter. A recent estimate is that the twelve states from Texas to Virginia had the capacity to export about 14 quads (quadrillion Btu's). They consumed about 21.5 quads and produced about 35.5 quads. In total, these twelve states account for over half of all domestic energy production.

Of course, this production is not uniformly distributed among the twelve states. Only four are net energy exporters--two of coal (Kentucky and West Virginia) and two of oil and gas (Louisiana and Texas). Not only are the other states net energy importers, but for the possible use of nuclear power plants, they have virtually untapped internal sources of energy. It is no surprise, therefore, that some in the region have concluded that nuclear energy is essential to the area's future. And, of course, it is no surprise that on security, health, and environmental grounds, others resist the idea.

The lengthy coal strike is certainly in everyone's mind as our energy options are considered. And no one can overlook the fact that excessive reliance on coal may make our energy supplies as uncertain as reliance on foreign sources.

What we would probably prefer is sufficient flexibility in our supply system that the nation is not dependent on the decisions of any one group. Whether we can possibly achieve that is unlikely but we should certainly strive for a policy that provides greater independence and flexibility than we now have.

Whether or not fueled by nuclear sources, the growth in electricity capacity will be an important feature of the energy scene in the Southeast. To cite some examples, it has been publicly announced that there will be 17 new generating units in North Carolina, 18 in South Carolina, 27 in Georgia, and 13 in Virginia. At the present time, 52% of the Southeast's electricity is generated by coal and 11% by nuclear energy. Of the known projected additions, 34% will be coal fired, but 51% will be nuclear fueled. This is a stronger commitment to nuclear generation than is true for the nation as a whole.

No matter what energy alternatives are adopted for the Southeast, it is well to remember the 1974 statement of the Southern Growth Policies Board:

> "In the past, mineral extraction was viewed as such an important part of the economic base that tax policy favored the exploitation of the South's resource by local and absentee firms alike. Now there are many who question whether those who profit should not also pay higher taxes. There is growing support for a higher percent of the revenue from the extraction of energy resources to be retained in the South for public and private benefits within the region. There is also increased insistence that pollution costs and other adverse effects associated with extraction be borne by producers and consumers rather than being passed on to local and state public agencies as external 'clean up' costs that must be borne by those who benefit."

It is important for us to remember, as the Growth Policies Board statement implies, that we don't really seek energy for its own sake. Rather, it is important for what it does to and for our way of life.

Higher energy costs and periodic restrictions of availability (for example seasonal cut-backs in natural gas supplies) vitally affect the lives and livelihoods of the people of the Southeast. To the extent that there's truth to the assertion that relatively cheap and abundant energy has contributed to the economic and population growth of the Southeast, changes in growth rates may be ahead.

For those who see a bright future of continued growth in the Southeast, attention to the biomass energy potential of the area is certainly warranted. I am extremely pleased that an area that is rich in timber and agricultural output is turning some of its attention to these sources of energy. Their potentials should not be overlooked as we seek assured energy sources to fuel the future development that's foreseen for the Southeast.

Since 1970, this has been one of the fastest growing regions in the U.S. and now accounts for 27% of the national population. Overall, the growth rate of population has been twice the U.S. average. After six decades of net outmigration, more people are now coming to the area than are leaving it.

I think that the people of the Southeast should view this as an opportunity and an obligation to preserve the advantages people are seeking. It should not be viewed as an indicator of victory in a mythical Sunbelt-Frostbelt conflict.

With this population influx comes vast potentials and knotty problems, not the least of which is the necessity to assure regional energy availability that is adequate in quantity and form.

There is still a large poverty problem in the Southeast--it has almost 25% of the national total of those below the poverty line--but per capita income is now growing faster than the U.S. average. And not surprisingly, the three fastest growing sectors that act as major sources of personal income involve extraction and processing of coal, natural gas, and petroleum.

There is still another way to say what energy means to the Southeast's livelihood. Its manufacturing industries consume 55,000 Btu's per dollar of value added, almost twice the national average. Energy supply and price will do much to help determine what the Southeast's economy will look like in the years ahead.

Change accompanies growth. Not only have we seen employment growing, but it has been growing with new emphases. The bulk of the post-1970 employment growth has not been in the traditional or "new" southern industries. Rather, it has been in professional and personal services in government, and in engineering and construction. These are activities which use below-average amounts of energy per unit of output and logic tells us that they will become more important in the future. As southern markets have grown and per capita incomes have risen, we can expect that labor, energy, and natural resources per unit of output will become less dominant. One evidence of this is the fact that in the first half of this decade, service employment grew by 26%, faster than the growth in manufacturing.

Present forecasts show continued rapid growth. Through 1990, southern per capita incomes are expected to grow 45% above the national average, population is expected to grow 36% faster, and employment 18% faster.

All this says that these are more than energy alternatives facing the South. There are economic development alternatives, environmental protection alternatives, land use alternatives, public services alternatives, and fiscal alternatives. The choices that are made among these in the public and private sectors--hopefully working cooperatively--will go far toward determining the kind of future we and our children enjoy.

AN OVERVIEW OF THE ENERGY SITUATION

Donald R. Pitts
Tennessee Technological University
And Tennessee Energy Authority

SUMMARY

Beginning with a historical review of our domestic pattern of energy usage, the current dependence of the United States upon dwindling petroleum resources is presented. The possible limit of petroleum usage is discussed, and recent oil production trends are presented. Coupling these with projected analyses of OPEC oil productive capability in the early 1980's indicates a serious worldwide as well as American energy problem in the next decade. The need for conservation and rapid development of application of alternative energy resources is discussed including quantitative projections of significant conservation efforts as well as estimates of domestic alternative energy resource capabilities.

INTRODUCTION - BACKGROUND

Historically, the United States has always had a large per capita consumption of energy. This has been true from the time of the Pilgrims to the present and resulted from our being a land with abundant energy resources. Even our earliest settlers found New England to be richly blessed with wood, whereas Europe and England were beginning to feel the effects of larger population density at that time.

Quite naturally, our earliest domestic energy source was wood, and our dependence upon this energy resource was almost total until the middle of the nineteenth century. As shown in Figure 1, wood supplied more than ninety percent of our national energy needs until approximately 1850, at which time coal began to become an important fuel.

As a side issue, it is interesting to note that the shortage of firewood resulted in near-panic conditions in England in the late 1840's. This shortage, hastened by the industrial revolution, caused the British to turn to coal as a major fuel, which was at first considered to be much less desirable.

Figure 1 shows the historical use pattern of major fuels -- wood, coal and petroleum -- for the period 1850 - 1980. Notice that this figure gives the percentage supplied with each resource and does not attempt to represent the numerical growth in use rate. Each of these resource use curves resembles a spread-out bell-shaped distribution curve. Of some importance is the fact that the growth section (from measurable use up to peak use) typically occurred over an approximate 60 year time span; for coal, 1850 - 1910; for petroleum and natural gas, 1890 - 1950. This is indicative of the time problem in converting a significant part of our energy usage to a new or previously unused resource.

CURRENT DOMESTIC USE

Turning to our current energy requirements, it is informative to categorize these into three sectors -- Residential and Commercial Space Conditioning, Industrial, and Transportation. For the year 1976, domestic use by these sectors is shown as Figure 2*. This shows for that year that Residential and Commercial use was the equivalent of 13.8 million barrels of oil per day; Industrial use was the equivalent of 13.7 million barrels of oil per day; and Transportation use was the equivalent of 9.5 million barrels of oil per day. Of major concern is the fact that 75 percent of the total combined usage was supplied by oil and natural gas, both of which are exhaustible and are being rapidly depleted.

FUTURE OF PETROLEUM

Perhaps the single most important energy question facing the world today is "how long will petroleum reserves last?" To get some insight to an answer to this question, let us examine Figure 3. Consider first the bottom part of this figure which is a bell-shaped distribution curve. Many experts feel that such a curve is a reasonable representation of the growth and decline in use of any depletable resource. The argument goes something like this: Conversion to use of a particular resource undergoes a growth period with consumer need increasing due to factors such as increased awareness of availability, increasing need due to growth in population, etc., for a depletable resource; however, the increased use rate or demand begins to be offset by increased cost (or difficulty) in procurement until the point is reached where these market factors result in zero growth. Finally, we enter a period during which the increased cost of production (obtaining) causes a general decline in usage. At this point in the discussion, it is informative to reconsider Figure 1, which is a curve of this type for wood, coal and petroleum. A widely-held theory is that when the growth rate levels off or reaches its maximum value, we have reached the one-half life point of the resource.

An equally important factor is the amount of a resource that can be produced. Petroleum geologists offer differing estimates of the available petroleum reserves. Some of the most credible estimates are in the range from 1740 to 2000 billion barrels of petroleum as the original amount of this resource on this planet. Considering one-half of this amount, the range would be from 870 to 1000 billion barrels, the band in the center of Figure 3. Turning to the question of when would we expect to reach the half-consumed point, we need to postulate a use rate and determine where we are with regard to cumulative usage. With regard to the latter, there is general agreement that we have used approximately 360 billion barrels through the year 1977. From this point the projected curve based upon the world's currently estimated energy growth curve (8% per year) indicates that we would intersect with the lower part of the one-half resource band in 1993, and that we would pass through this band in about 2 years.

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*All Figures and Table 1 of this paper were adapted from DOE furnished slides except as noted.

Even worse, if we continue the 8% annual growth rate, we would deplete essentially all of the world's petroleum resources by the year 2000. Clearly, market factors and economics will prevent such a complete early exhaustion of these resources, but even a zero - growth curve would indicate a one-half depletion between 2003 and 2008. This in itself constitutes a sobering background for our consideration of alternative energy sources, but the situation is more serious for the United States than this would indicate.

In Figure 4, we have plotted our domestic crude oil production and imports through 1975. At this point, we should note that our domestic production peaked between 1970 and 1971, and this may be indicative of a one-half depletion of our U. S. petroleum reserves. Note also the very rapid increase in American dependence upon imported crude oil -- our imports reached 45 billion dollars in 1977, a major factor in our imbalance of imports and exports. In the recent past, the only factor slowing our increase in imported oil consumption was the 1973 Arab oil embargo.

Actually, the U. S. became a net importer of petroleum in 1969. Until that time, we controlled, to a very large degree, the world price of oil. It is often said that until 1969 the world price of oil was determined in the Gulf of Mexico; since that time it has been controlled in the Gulf of Suez. With domestic production continuing to decline, our dependence upon oil producing and exporting countries (OPEC) oil increases with serious implications for our national economy.

This alone should be sufficient incentive for Americans to conserve energy and to turn to alternative resources. Much of our population, unfortunately, does not believe or understand the seriousness of this problem. Even many of those who do believe that we have a significant domestic petroleum production problem believe that the problem is simply one of economics and that we can purchase all the fuel we need. A further insight into this fallacy is afforded by Figure 5 which shows how new discovery results have declined worldwide in the past 25 years. This decline is primarily due to an ever diminishing resource available for discovery. Perhaps even more disturbing is the projection given in Figure 6 which indicates that the OPEC petroleum productive capacity and the demand for OPEC oil will intersect in 1983-84, with demand continuing to increase. With the resulting world supply shortfall, it is highly unlikely that costs will remain stable at anything resembling current prices after correction for annual escalation.

ALTERNATIVE RESOURCES

Usable domestic energy resources include natural gas, petroleum, geothermal, oil shale, coal, uranium, solar, fusion, wind, and biomass. Recent DOE projections of the extent of most of these resources are presented in Table 1. To place the quantities of this table in proper perspective, the 1975 domestic energy consumption was estimated to have been 71 quads (one quad is 10^{15} Btu) and the estimated U. S. cumulative energy requirement for the period 1975 - 2000 is estimated to be 2900 quads, unless reduced by extensive conservation efforts.

It is readily apparent from this table that the most easily used resources are in short supply, while ones more difficult to use are generally more plentiful. The exception to this is coal, which is both easily used and available. At this point we should note that our domestic recoverable coal supply represents approximately three times as much recoverable energy as the entire mid-east oil reserves. Further examination of this table indicates that natural gas and petroleum are the smallest of our domestic resources. A few comments about each of these resources will help in defining our current problem.

While geothermal energy resources are of significant magnitude, most of these are located in the westernmost states. Further, current technology is available only for use of hydrothermal resources for production of electricity; the use of magma and hot dry rock for production of electricity requires further R and D.

Oil shale may offer a very significant source of liquid hydrocarbon for the future. While the estimate of recoverable energy from oil shale given in Table 1 is in consonance with the other estimating techniques used in preparing this table, some industry sources place the estimate for this resource at a considerably higher level. For example, one petroleum resource company actively pursuing in situ processing estimates a total of 1818 billion barrels of recoverable oil shale in the Green River area of Colorado, Utah, and Wyoming alone. And this amount is roughly equivalent to the total of the world's original petroleum deposits. This amount, incidentally, is approximately 50 percent larger than the 5800 quads of Table 1. Major problems with this resource include disposal of a significant overburden (even for the in situ process) and production costs. Estimates of production costs range from approximately $13 to $25 per barrel of crude; this wide range reflects serious differences of opinion between industry sources due to lack of operational experience. At present, one company is proceeding with an in situ pilot plant program. As a final note concerning oil shale, the fuel obtained could not be as cheaply processed into automotive fuels, etc., as crude oil (petroleum).

The availability, extent, and usefulness of coal, as well as environmental problems associated with application of some grades, are generally widely known and will not be discussed herein. This large domestic resource, however, is probably the most important one for the time frame from now to say the year 2020. In addition to the 13300 quads shown in Table 1, in situ production of other forms of fuel from coal can be very significant.

Turning to uranium, our present national policy of using light water reactors only limits our recoverable energy from domestic supplies to 1800 quads. If we were to develop breeder reactors, however, this resource capability would expand to 130,000 quads. Unfortunately, the present Administration has chosen not to develop the breeder reactor. In light of the pending worldwide energy crisis due to petroleum shortages, I believe that our failure to proceed vigorously with a breeder reactor program is a major mistake that will not be easily corrected.

The only alternative energy source which is renewable (or nondepletable) and theoretically capable of meeting all of our future energy needs is solar energy. The practical limitations on its development, however, are quite restrictive. A major drawback is unfavorable economics at the present time. As a simple illustration of the problem, current state-of-the-art technology for solar heating a 1800 square foot residence in a southeastern U. S. city with 4000 degrees days of annual heating requirement dictates the use of approximately 600 square feet of flat plate collector surface costing about $7800 for the collectors (not installed). This coupled with the installation, energy storage subsystem, and control subsystem costs typically results in an approximate system cost of $15,000 - $20,000. And the solar system would also require an auxiliary heating system for extended (say beyond three days) inclement winter weather.

Finally, among our alternative depletable domestic energy resources, fusion is the largest. Clearly, however, the present status of the fusion R and D program and the very long projected lead time for its development to commercialization indicate that this will not be a possible contributor until well into the next century.

While this has not been a very detailed overview of alternative energy resources, some of the later participants in the program will bring us up-to-date on the status of several of these.

CONSERVATION

In the preceding we have considered several alternative energy resources for domestic use. In view of the serious worldwide petroleum problem, we need to proceed toward vigorous development of all of these. Even so, it will require a significant time period to carry development through to commercial availability. Examples of the time required for development of various well-known energy systems are shown in Figure 7. These range from five years for a coal mine to greater than ten years for a light water reactor nuclear plant. It should be clear that the time for commercial development of a new untested technology, such as in situ oil shale development, is very difficult to predict. For new technologies, environmental permitting, etc., may be very time consuming and recall from Figure 1 that it historically requires 60 years to bring a new major energy resource to full commercialization.

In the near-term time frame we must focus a major effort on conservation. A major question is "Can we in the United States reduce our per capita energy consumption?" Turning to Figure 8, we have plotted the per capita energy consumption vs. per capita gross product for a large number of western countries. The gross product value per capita is a measure of what can be afforded for energy expenditures. In this figure, we see that countries such as Canada and the United States, both having large energy deposits, have traditionally been energy wasteful, whereas European countries with limited energy resources have been conservative. The point of this figure is that the economic standard of living is not directly related to energy consumption. Surely the Swedish have a standard of living comparable to that of the North America countries, but at a lower per capita energy usage. This indicates that there can be major energy savings through extensive conservation efforts in the United States without resulting in serious economic or living condition dislocations.

As a quantification of conservation goals, the DOE (ERDA) projection of total energy requirements for the United States from 1975 to 2000 is 2900 quads without extensive conservation and 2400 quads with extensive conservation efforts. Certainly, this is a reduction worth our best efforts.

CONCLUDING REMARKS

The United States has domestic energy resources that are capable of serving our projected needs for many centuries. Our problem is the immediate (and serious) task of developing suitable ones to the state of commercial availability to meet our many needs and to implement extensive conservation practices to ensure a high quality of life for future generations. I am confident that we can and will solve the resource development problems and achieve major reductions in energy waste through conservation.

TABLE 1

DOMESTIC ENERGY RESOURCES

RESOURCE	EXTENT (QUADS)
Natural Gas	1030
Petroleum	1100
Geothermal Hydrothermal(464 Quads) Hot Dry Rock(2650 Quads) Magma (320 Quads)	3434
Oil Shale	5800
Coal	13300
Uranium Light Water Reactors (1800 Quads) Breeder Reactors (128200 Quads)	130000
Solar	43000/yr
Fusion	3×10^{12}

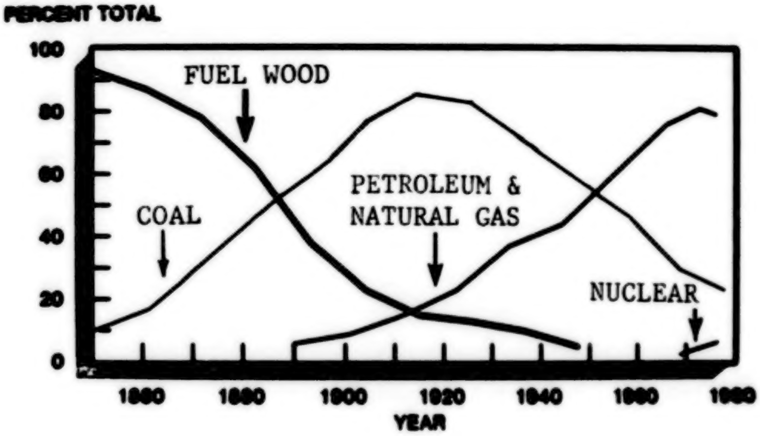


Figure 1.- U.S. energy consumption patterns.

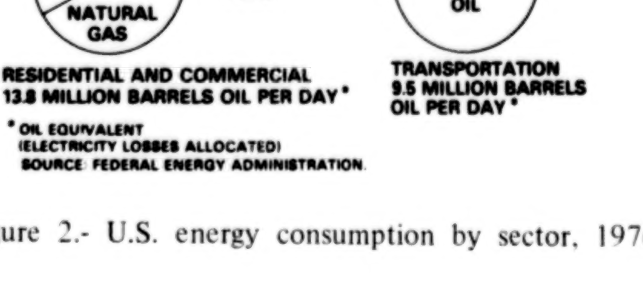


Figure 2.- U.S. energy consumption by sector, 1976.

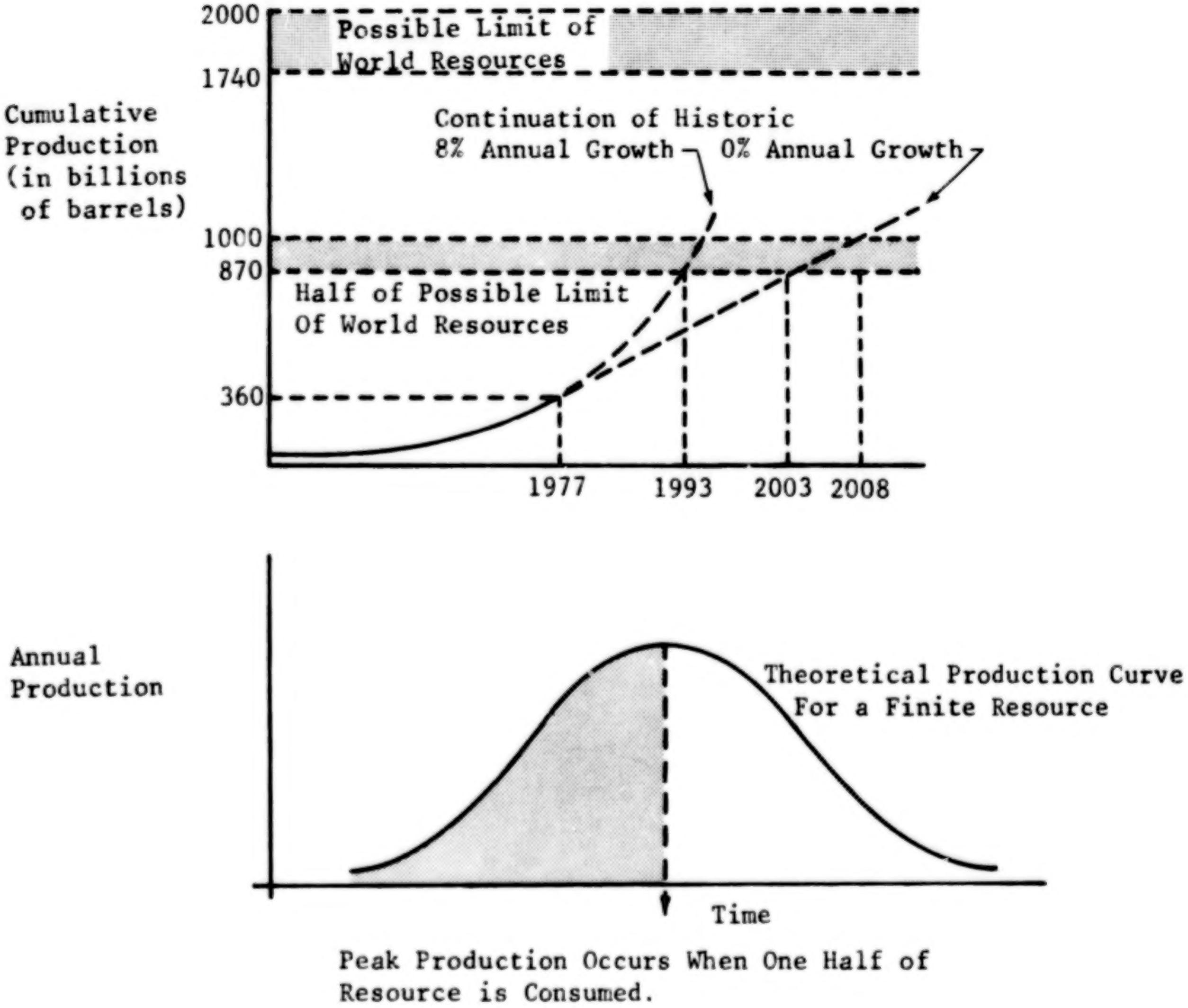


Figure 3.- Current and projected world production of petroleum.

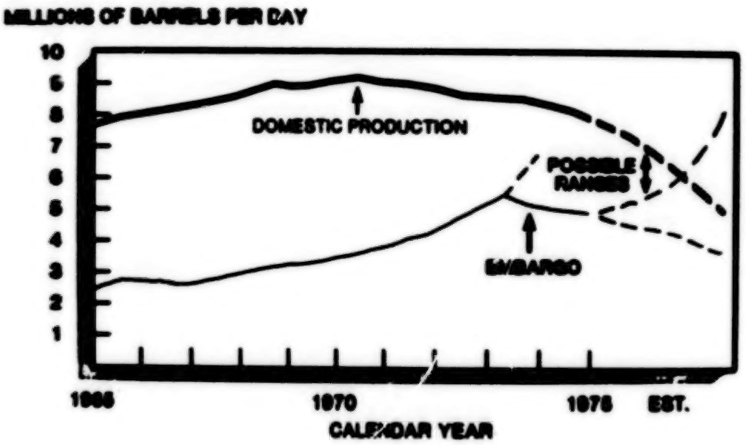


Figure 4.- Comparison of domestic crude oil production to oil imports.

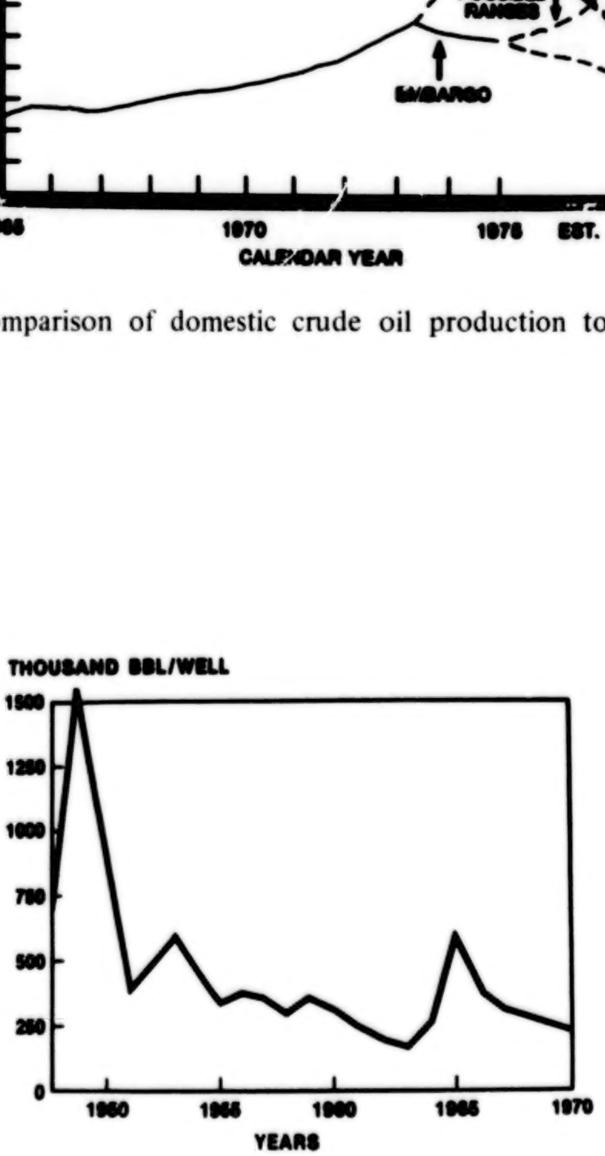


Figure 5.- Declining oil discovery results.

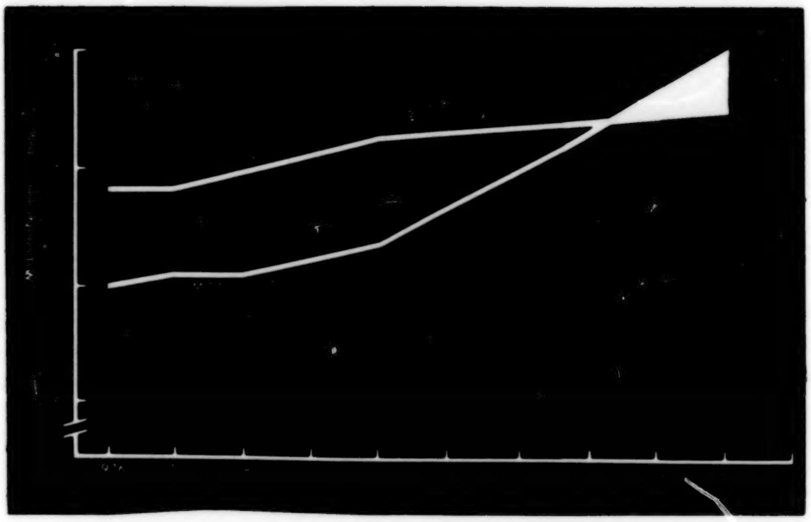


Figure 6.- OPEC oil: The supply/demand gap (adapted from State & County Administrator, Vol. 2, No. 1, Nov., 1977, p. 13).

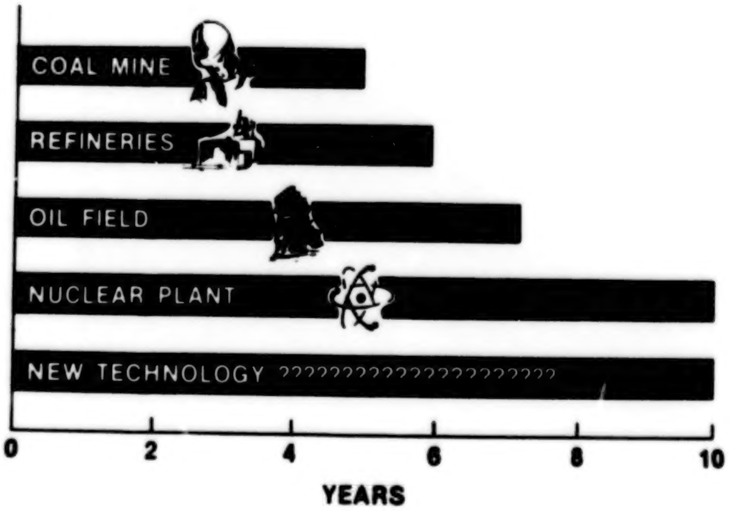
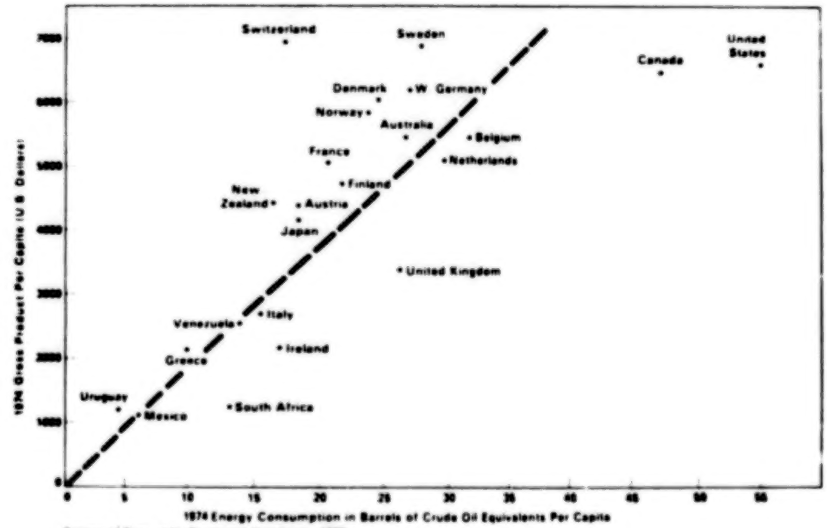


Figure 7.- Typical lead times.



Source of Data: U.N. Statistical Yearbook, 1975

Figure 8.- Energy consumption per unit of gross national product.

ALTERNATIVES IN SOLAR ENERGY*

Donald G. Schueler
Sandia Laboratories

SUMMARY

Although solar energy has the potential of providing a significant source of clean and renewable energy for a variety of applications, it is expected to penetrate the nation's energy economy very slowly. The alternative solar energy technologies which employ direct collection and conversion of solar radiation are briefly described in this paper.

INTRODUCTION

The continuing rapid depletion of fossil fuel resources is one of the most important long-term issues facing the United States. Solar Energy has the potential of providing a significant source of clean and renewable energy for a variety of applications and is one of a limited number of alternative energy sources that the nation must begin turning to (ref. 1). To this end, the United States Department of Energy (formerly the Energy Research and Development Administration) has implemented an aggressive program of solar technology research, development, and demonstration (refs. 2 and 3). A goal of the National Solar Energy Program is the creation of a comprehensive solar energy industry that can supply a significant fraction of the nation's energy needs by the year 2000.

This paper will briefly review each of the major direct solar energy conversion and utilization technologies.

SOLAR ENERGY UTILIZATION PROCESSES

Solar energy is a unique form of energy because of the many conversion processes through which it can pass to useful energy products such as fuel, mechanical power, heat, and electricity. Solar energy is collected through many natural processes which create the winds and ocean currents, drive the hydrologic cycle, and make possible photosynthesis in plants. These natural

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*This work supported by the U. S. Department of Energy, Division of Solar Technology

processes constitute the conversion of solar energy into many different forms of energy, a small fraction of which is stored in plants or through the formation of fossil fuel, but most of which is ultimately degraded into low-temperature heat and radiated back into space.

The following sections briefly describe solar conversion and utilization processes that make direct use of solar radiation through the use of man-made collectors. Indirect forms of solar energy utilization such as ocean thermal energy conversion, wind energy conversion, and photochemical conversion are not discussed.

Solar Water Heating

Solar water heating for domestic use appears to be the most competitive of the solar technologies. Simple flat panel collectors are widely used and the water heating system typically consists of a collector which either directly warms water or uses a heat-transfer medium to indirectly heat water. Such systems generally provide from 50 to 70% of the total energy required and back-up gas or electric heaters provide the balance.

Solar Space Heating and Cooling

Residential and commercial space conditioning is an important but slower growing solar technology compared to solar water heating. Solar space heating systems are commonly classified as "active" or "passive" systems. Although their distinction is not always clear, active systems usually involve a flat panel or concentrating solar collector, a heat-transfer medium, a thermal storage system, and a heat distribution and control system. Passive systems incorporate a series of architectural modifications to maximize and distribute solar heat gain during the winter and to minimize it during the summer. Most solar heating systems maintain some form of conventional back-up heating system (gas, oil, coal, electrical) for use during prolonged periods of overcast weather.

Solar cooling (air conditioning) is accomplished by using solar energy as a heat source for an absorptive refrigeration system or by using solar energy to drive a heat engine which in turn drives the compressor of a mechanical heat pump. Because solar cooling requires higher temperature input (at least 100°C) and specialty equipment, it is not likely to grow in pace with solar heating.

Regional variations in conventional energy costs, energy usage, and solar insulation require a region-by-region analysis of the economics of solar space conditioning systems. Market penetration of solar residential/commercial space conditioning is likely to proceed very slowly because it is largely limited to new construction (ref. 1).

Industrial Process Heat

The single largest industrial use of energy is for hot water and steam in the 50° to 180°C temperature range (ref. 4). Although the potential for solar capturing this market is uncertain (ref. 1), its mid-temperature thermal requirements are within the performance range of some flat panel collectors and most distributed concentrating collectors.

Solar Electric Generation

Energy usage for electrical generation is a large and fast growing demand. Solar technologies for electrical generation are solar thermal conversion and photovoltaic conversion. Solar thermal conversion involves the concentration of solar energy on thermal receivers through the use of either distributed concentrating collectors or central receiver systems such as represented by the "power tower" concept. A heat-transfer fluid is used to convey thermal energy from the receiver through a heat engine, such as a conventional steam turbine, to generate electricity. Photovoltaic systems employ direct solar-to-electric energy conversion in solar cells similar to those that have been used to power spacecraft for many years (refs. 4 and 5).

Except for small, remote power systems, solar electric technologies are currently too expensive to compete with conventional generation methods. The major emphasis in the Department of Energy programs is, therefore, development of low-cost solar electric technologies aimed at significant applications in the year 1990-2000 time frame.

Solar Total Energy Systems

Solar total energy systems combine both thermal and electrical conversion processes to provide a major fraction of the total energy requirements of residential, commercial, and industrial loads. In the case of solar thermal total energy systems, the reject heat from the heat engine used to produce electricity is captured and used for low and mid-temperature thermal applications. Such systems are similar to conventional on-site cogeneration systems (ref. 6). Photovoltaic total energy systems employ combined photovoltaic and thermal collectors which may be of either the flat panel or concentrating type (ref. 7).

THE SOLAR RESOURCE

The amount of solar energy incident on a solar collector depends strongly on both its geographic location and geometry (ref. 8). Figures 1 and 2 are solar radiation availability maps for the United States showing the average daily solar radiation (kwh/m^2) available to collectors of two different geometries in the winter. Figure 1 is the average daily availability of total solar radiation on a south-facing, 45° tilted surface and Figure 2 is the average daily availability of direct-normal solar radiation incident on a fully tracking collector surface. More extensive data of this type are available (ref. 8) and can be used to evaluate and compare the performance of collectors of different types in locations throughout the United States.

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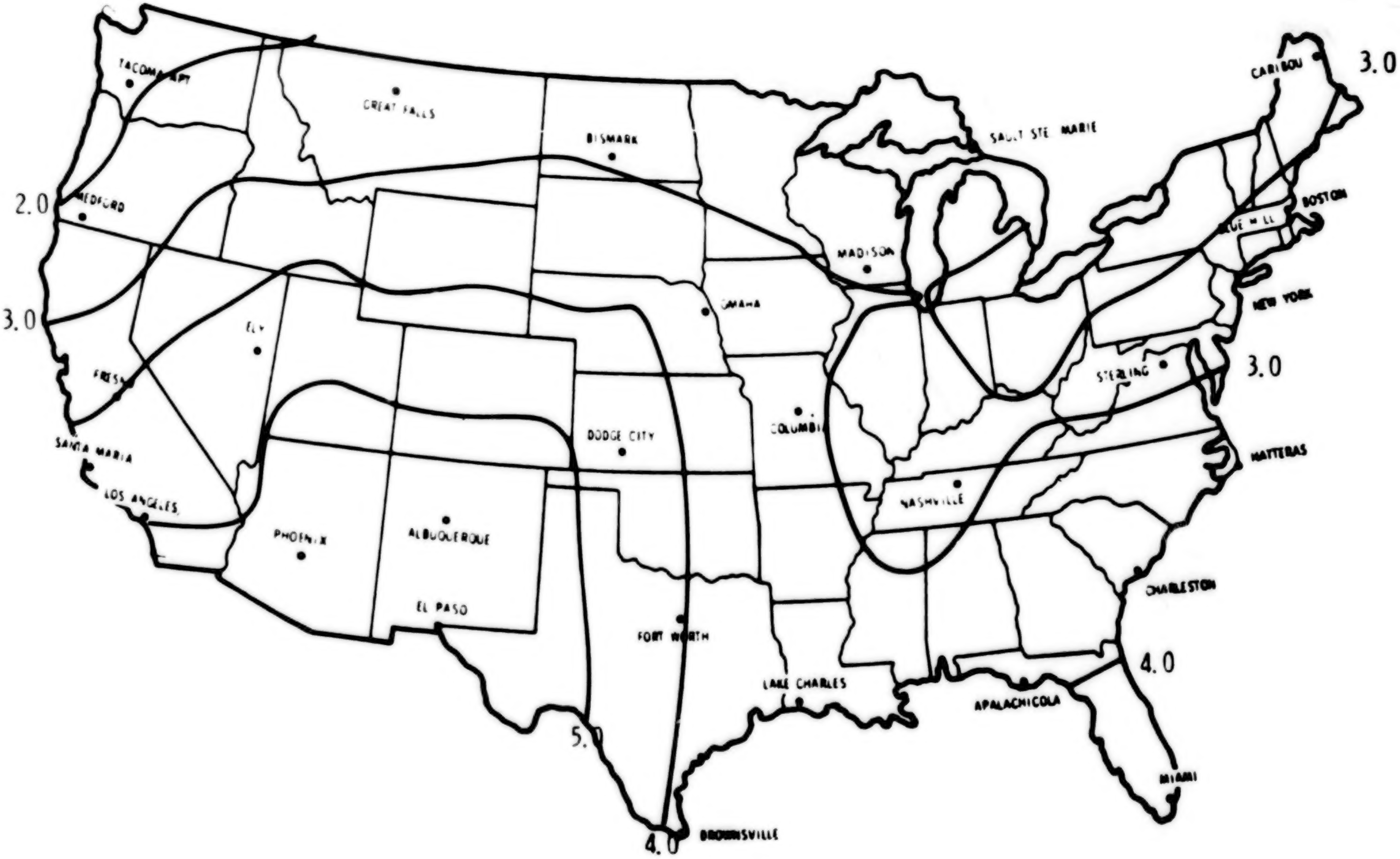
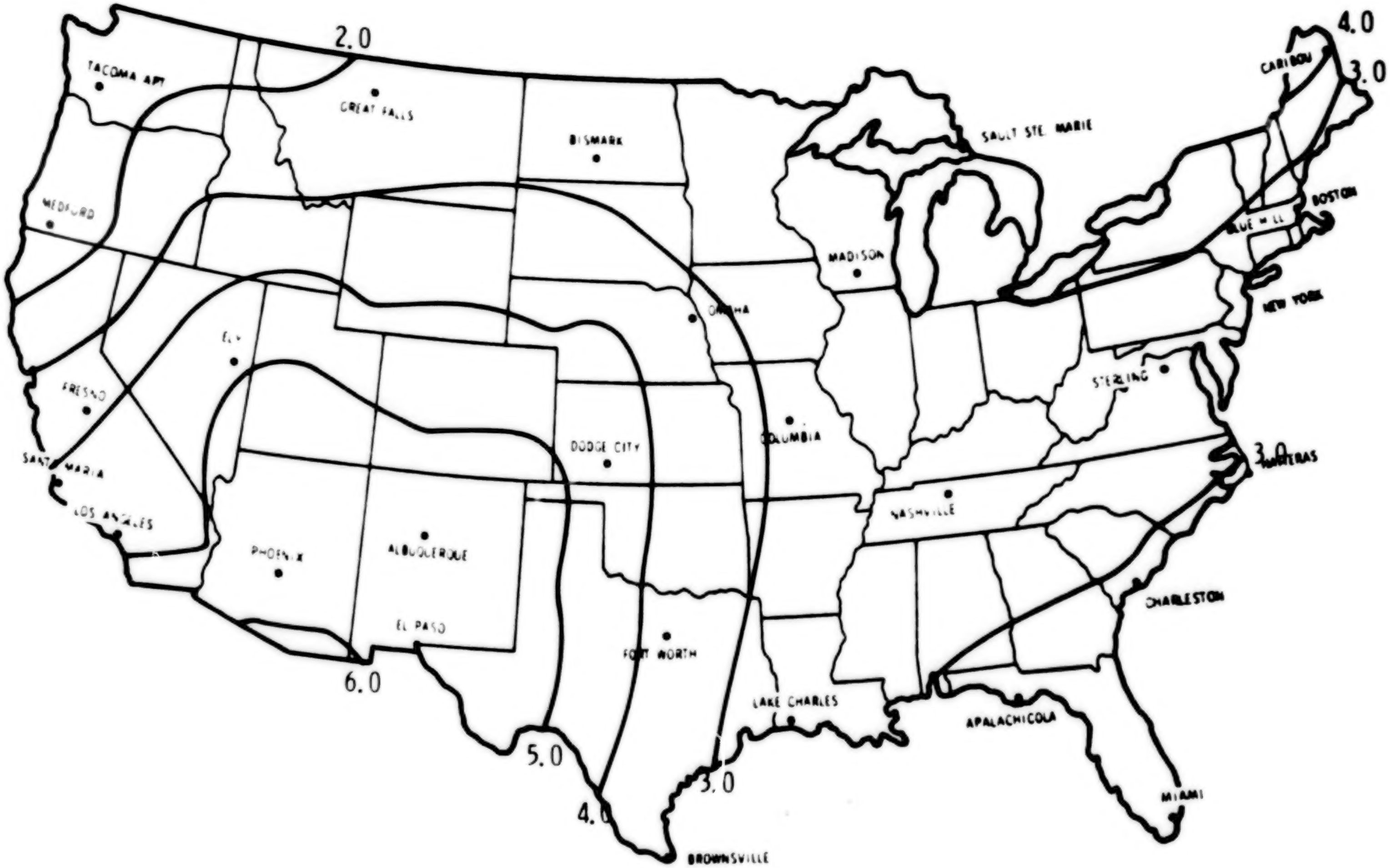

TACOMA APT
GREAT FALLS
BISMARK
SAULT STE MARIE
CARIBOU
3.0
BOSTON
BLUE HILL
2.0
MEDFORD
MADISON
OMAHA
NEW YORK
3.0
ELY
FRESNO
STERLING
3.0
SANTA MARIA
DODGE CITY
COLUMBIA
HATTERAS
NASHVILLE
LOS ANGELES
PHOENIX
ALBUQUERQUE
EL PASO
CHARLESTON
FORT WORTH
4.0
LAKE CHARLES
APALACHICOLA
5.0
MIAMI
4.0
BROWNSVILLE

Figure 1.- Average daily availability of total solar radiation on a sourth-facing, 45° tilted surface for the U.S. in the winter, kwh/m^2.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GREAT FALLS
BISMARK
SAULT STE. MARIE
CARIBOU
MEDFORD
BLUE HILL
BOSTON
MADISON
NEW YORK
OMAHA
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FRESNO
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LOS ANGELES
NASHVILLE
PHOENIX
ALBUQUERQUE
CHARLESTON
EL PASO
FORT WORTH
6.0
LAKE CHARLES
APALACHICOLA
5.0
3.0
4.0
MIAMI
BROWNSVILLE

Figure 2.- Average daily availability of direct-normal solar radiation for the U.S. in the winter, kwh/m^2.

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WOOD ENERGY-COMMERCIAL APPLICATIONS OUTSIDE THE WOOD INDUSTRY

Robert P. Kennel
Vice President
Ultrasystems, Inc., Washington, D. C.

SUMMARY

Wood energy is being widely investigated in many areas of the country because of the many obvious benefits of wood fuel such as the low price per million Btus relative to coal, oil, and gas; the wide availability of noncommercial wood and the proven ability to harvest it; established technology which is reliable and free of pollution; renewable resources; better conservation for harvested land; and the potential for jobs creation. The Southeastern United States has a specific leadership role in wood energy based on its established forest products industry experience and the potential application of wood energy to other industries and institutions. Significant questions about the widespread usage of wood energy are being answered in demonstrations around the country as well as the Southeast in areas of wood storage and bulk handling; high capitalization costs for harvesting and combustion equipment; long term supply and demand contracts; and the economic feasibility of wood energy outside the forest products industry.

INTRODUCTION

The Southeastern United States has increasing energy needs based on an expanding population and economy. The region has necessarily depended upon energy supplied by other regions and nations since there are few commercial fuel sources of indigenous oil, gas, coal, or uranium within the region, although hydroelectric power is available. The region has thus begun to investigate the feasibility of other potential sources of energy, such as solar energy or wood fuels, which are available in abundance within the region.

There are estimated by the U. S. Forest Service to be over one billion tons of noncommercial wood that could be used annually for fuel in this country. The estimates for the Southeastern United States are approximately one third of that amount in the nature of logging residuals, thinnings, noncommercial growth, and industry wastes. For example, there are 20 million acres of commercial forest in North Carolina, and it has been estimated that approximately 7% of the state's primary energy needs could be met using an annual 24 million tons of noncommercial "junk" wood (ref. 1), without impacting the important wood industry within that state. The State of Georgia estimates over 40 million tons of wood fuel available annually from its 24 million acres of commercial forests as well as over 30 million tons of cull timber.

WOOD ENERGY RATIONALE

The arguments that can be made for the increased use of wood energy are indeed powerful. Most of the reasons for wood fuel usage have been around for a long time and the positive characteristics can be summarized briefly as follows:

- o Inexpensive - wood fuel in the form of whole tree chips cost less than $1.30 per million Btu's. Industrial wood wastes are even less.
- o Established Technology - commercial wood harvesting and combustion technologies have been adequately demonstrated by the wood industry for system technical feasibility.
- o Renewable - wood energy is one of the few renewable resources other than solar, wind, and biomass. Moreover, it is here today while the other technologies require significantly more research.
- o Nonpolluting - wood contains less than 0.1% sulfur, far less than the lowest sulfur coal. Combustion temperatures are low enough that nitrogen oxides are not a problem. The stack particulates are easily captured by low cost pollution control equipment, and the ash even has excellent soil nutrient value.

- Land Value Improvement - harvesting by thinning or clear cutting increases the residual land value. Reforestation incentives have recently been dramatically improved. Whole tree harvesting also eliminates forest residues upon which forest fires thrive.

- Jobs Creation - new jobs are created in the rural economy where unemployment is high. The fuel supply is not so sensitive to labor disputes.

In addition to these obvious benefits, there are also dynamic conditions which have evolved over the past years that are helping to create the current climate for increased wood fuel usage.

- Conventional Fuel Concerns - the costs of other combustibles fuels is currently high ($1.40 per million Btu's for coal, $2.50 for oil, and $3.25 for gas), and they are all going higher. There is the ever present danger of fuel supply interruption due to strikes, shortages, and embargoes for coal, gas, and oil, respectively, while wood is not nearly so susceptible. There are also "balance of payment" implications for the given state, region, or nation. Moreover, wood fuel is available just about everywhere.

- Maturation of Wood Harvesting Techniques - the whole tree chipping technology has matured over the past five years and is currently recognized by loggers as a dependable and economical harvesting technique for most forests.

- Energy Independence by Wood Industry - there is an increasing move toward energy self sufficiency in the wood industry, particularly in the pulp and paper industry. Most of the wood energy system parameters have been proven within the wood industry and are available for economic evaluation in applications outside the wood industry.

- Forestry Endorsement of Environmental/ Conservation Benefits - the U. S. Forest Service, State Forestry officials, Forestry Schools, and Wood Industry Foresters, are all pushing the value of good forest management through selective harvesting. There is also a growing recognition of the need for a comprehensive forest inventory for total biomass.

- Continuing Unemployment - there is a recognized need for new jobs creation in rural areas as well as urban; and wood energy allows the creation of healthy, productive jobs in the forests of rural areas.

Despite these many positive statements about why wood should be more widely used as a fuel source, there are some concerns and potential problems with wood energy which must be openly addressed. The primary concerns and potential problems can be summarized under the following categories:

Technical

Wood storage questions remain for whole tree green chips. The number of wood pile "war stories" abound, but it is also known that wood piles of as much as 8000 tons have existed for 18 months at Champion Paper (Gaylord, Michigan) without problems.

Bulk fuel handling is required. Handling is similar to that of coal but with a 10:1 larger bulk ratio for green wood. Handling equipment for loading/unloading, transportation, conveyance, or storage has not yet been optimized or standardized.

Economic

High capitalization costs exist for the small logger or industry that would harvest or burn wood for energy. New whole tree harvesting equipment costs as high as $500K for a single harvesting team; a new wood burning steam boiler plant costs in the range of $15-40 per pound per hour of steam generation; and electrical power generation capability costs in the range of $600-700 per kilowatt.

The new woodyard brokering role for long range supply and demand for wood fuel has not yet been demonstrated to be commercially feasible.

Current low stumpage prices from private landowners will probably rise as wood becomes recognized as a fuel commodity.

Cogenerated electric power sold by an industry to a utility currently brings very low prices for off-peak hours.

Political

Limited coordination exists among all the wood energy project elements that are occurring around the nation. There is no overview responsibility currently assigned at the federal level to insure something so simple as information exchange among the many wood energy projects around the nation.

There is no recognized spokesperson of national stature such as the President, a Congressman, or Department of Energy leader who is making the case for wood energy on a national level. Most other fuels have strong existing lobbies.

There has not yet been significant dialogue between the evolving wood energy interests and the established institutions that would possibly be impacted by increased fuel usage. These include various segments of the wood industry that might perceive increased competition for wood sources or the coal, oil, and gas industries with which wood might be seen as competition.

The federal and state governments and non-wood industry are only in their embryonic thinking on wood energy since there has not been a significant national exposure. Furthermore, there have not been sufficient demonstrations to move any significant segment of the economy toward wood energy, although such demonstrations are in planning. Finally, the legal and regulatory issues affecting power generation in particular are not yet defined with (1) the National Energy Act not acted upon; (2) subsequent government policy decisions on such issues as cogeneration not yet made; and (3) subsequent industrial/utility policy decisions not yet developed.

The utilization of wood fuel outside the wood industry in the Southeastern United States is dependent upon the overall parameters summarized in Figure 1.

WOOD ENERGY STATE-OF-ART

Commercial Applications

Around the United States there has been an increasing commercial application of wood energy within the wood industry. Most pulp and paper mills have already installed or are in the process of installing waste wood energy sources using bark and "black liquor" residues for process steam and power. The pulp and paper industry is rapidly becoming more energy self-sufficient with some places such as Weyerhauser at Plymouth, North Carolina, becoming 85% self-sufficient. Many sawmills and veneer mills have already converted their wood wastes to process steam and kiln drying. Some of these mills are installing cogeneration capability for electrical power as well, particularly in Arkansas, California, and Oregon.

The wood industry obviously controls its own wood waste fuel supplies. Outside the wood industry there are currently only a limited number of commercial wood burning systems. The City of Eugene, Oregon, has successfully burned hogged wood wastes for over 37 years as a part of their municipal power production (some 275,000 tons per year generating 33MW of power). The fuel they have used has been Douglas Fir wastes (approximately 80% bark, 20% chips) combined in travelling grate boilers with 600 psi, 800° F steam into steam turbines. The City of Eugene is currently working with Weyerhauser for waste wood cogeneration in which the city purchases the excess power from Weyerhauser at 9 mils/kWh.

Western State Hospital in the State of Washington has been burning Woodex pellets (18,000 tons consumed last year) in a converted coal boiler which required only stoker modifications and adjusted air to fuel ratios. They paid $30/ton for the pelletized dry fuel which included $8/ton freight for a 235 mile trip.

Russell Textiles in Alabama has been burning wood for over two years with advertised savings of $1.00 per million Btu's over the fuel oil they had been using.

Russell uses 20 tons/hour of purchased wood wastes in a pin hole grate, spreader stoker water tube boiler to generate 120,000 lbs./hour of 200 psi process steam. Russell now plans to add an additional 100,000 lbs./hour boiler using wood fuel.

The City of Burlington, Vermont has been supplied with a 10 MW portion of its power over the past few months in the nation's first public utility using wood chips as the primary fuel. The city has been burning 75% wood chips and 25% oil in a converted coal burner and generating power at 21 mils/kWh. They are paying $12/ton for wood chips. The city has completed a bond issue which was approved by the voters in March to construct a 50 MW plant.

Demonstrations

Numerous demonstrations are planned around the country to evaluate various parameters of the supply and demand aspect of wood energy. Only those that appear to have some significant impact on the use of wood in that particular state or region will be discussed here.

In general, there are a number of whole tree chip, wood wastes, and pelletized combustion demonstrations going on around the country. The Department of Energy has a program in Maine under contract to Wheelabrator-Frye Clean Fuels to study the harvesting and combustion feasibility for a large (~ 50 MW) power plant. The State of Michigan is considering a series of direct combustion power generators in the 10-20 MW range for Western Michigan and the Upper Penisula. Morbark Industries is proposing this concept tied into the Wolverine Electric grid (REA Generating and Transmission organization in Michigan).

Whole tree chips have also shown the ability to provide lower cost and pollution benefits when burned 15% by weight with high sulfur coal in the power plant at Grand Haven, Michigan (ref. 2). A Vermont mental institute plans to generate 7.5 MW of power using only wood chips.

Numerous pelletizing demonstrations for combustion in existing coal-fired boilers are occurring around the country including one at the Collins and Aikman plant in Albemarle, North Carolina. There are also a number of pyrolysis gas demonstrations around the country with units provided by Tech Air, Monsanto, Weyerhauser, Garrett, and others. With Tennessee Valley Authority technical support, Maryville College in Tennessee will be using wood fuel through a new ENERCO gas pyrolysis system developed at Penn State University. The system is to generate up to 40,000 lbs./hour steam on a five-year wood waste supply contract at $4-7 per ton by Veach-May Wilson Forest Products in Alcoa, Tennessee.

Research

Most of the advertised research on wood fuel comes under the Fuels for Biomass program within the Energy Technology Division of the U. S. Department of Energy. The Fuels for Biomass program (ref. 3) clearly states a limited interest in direct combustion concepts and is pursuing a program with a stated objective to "develop the capability of converting renewable biomass resources into clean fuels, petrochemical substitutes, and other energy-intensive products that can supplement similar products made from conventional fossil fuels." The Fuels for Biomass program's interest in wood products is to develop liquid fuels (alcohols, fuel oils), gaseous fuels (SNG, hydrogen), and petrochemical substitutes (Ketones, higher alcohols) by biochemical and thermochemical processes. Over the past few years there has been a heavy effort on biomass resource inventories and enhanced biomass growth.

Development Planning

The State of Georgia has proposed to the Department of Energy a comprehensive plan for a Wood Energy Center in the Southeastern United States. This would be followed later by Regional Wood Energy Centers in the Northeast, Great Lakes States, and Northwest. It is believed that the Department of Energy has received the proposal favorably.

The Southeastern Wood Energy Plan involves a number of economic and environmental support studies; a series of wood energy demonstrations in direct combustion and gasification for steam and power production; a series of near-term technology diffusion tasks; and a follow-on research program in areas such as retrofit gasification and wood chemicals processing. Although funded and sponsored by the Department of Energy, the Regional Wood Energy Centers would have a degree of decentralized authority to develop the wood energy programs along with different sociological, economic, environmental, and technical parameters specific to a given region.

The State of North Carolina is developing a complementary wood energy program with multiple parameters being investigated. Governor Hunt has appointed a Wood Energy Coordinating Group and a staff to implement the program. This program covers; (1) a wood demonstration for Western Carolina University in which the economics of harvesting and combustion would be evaluated; (2) a wood research and demonstration project at an institution in Raleigh to technically evaluate the parameters of wood handling and combustion; (3) a wood yard marketing facility to collect, store, and process wood fiber to evaluate the fuel demand in a particular geographic area such as Morganton; and (4) an assessment of the feasibility of wood-fired power generation for industrial cogeneration or power plants, with emphasis on the Coastal Plains area. Ultrasystems has recently completed a study for the State of North Carolina in this area.

The U. S. Forest Service has also initiated comprehensive planning with respect to its role in research and development in fuel resources. At a minimum, it is expected that new forest inventory procedures will be implemented to determine the total available forest product, part of which might be used for fuel. It has apparently not been decided whether the reinventory procedures will be based on Young's (refs. 4 and 5) utilization of the complete tree including roots or Keays' (ref. 6) above ground portions as the basic timber unit.

Wood Energy Compendia

There are two known organizations that are taking a nationwide inventory of wood energy projects although their reports are not yet available. NorWest of Seattle, Washington, is completing a contract to the Department of Energy on the state-of-art of wood combustion. The Bio Energy Council of Washington, D. C., under Mellon Foundation funding, is completing an inventory of all bio-energy projects. They will also develop an industry applications manual as a follow-on.

CONCLUSIONS

Although an overview paper cannot explore all the parameters of wood energy for the Southeastern United States, there are some conclusions that can be drawn from the work around the country that affects the application of wood energy outside of the forest products industry.

First, the various wood energy demonstrations currently planned in the Southeastern states are badly needed to evaluate various economic, environmental, and institutional parameters. Several state governments and the Appalachian Regional Commission are taking the lead in this area.

Wood fuel is abundantly available in the region although prices are not yet established. The price for harvested wood chips fuel will fall between the low $3-5 per ton for industrial wastes and the $10-14 per ton for quality pulp and paper chips, probably toward the high end.

Wood combustion technology is available to efficiently produce steam/electricity on a direct or cogenerated basis. Green wood fuel can be combusted in packaged boilers in the 10-60,000 pounds of steam per hour range at an installed cost of $15-30 per pound of steam capability. Electrical power generation capability in 1-5 megawatt modules can be installed in the $600-700 per generating kilowatt range. Cogeneration of electricity and steam will significantly reduce the cost of the steam. In the Southeast, the industries most amenable to wood energy utilization are the textiles, clay products, and chemicals (the latter on a cogeneration basis).

Federal legislation and policy development is still needed to assist commercialization of wood energy. That is expected to come through the national energy legislation in the areas of increased investment tax credits, loan guarantees, and cogeneration policy for industry interaction with utilities.

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LAND

- Ownership
  - Private
  - Corporation
  - Government
- Terrain
  - Coastal Plain
  - Piedmont
  - Mountains
- Forest Type
  - Hardwood
  - Softwood
  - Mixed

HARVEST

- Supply Source
  - Plant Wastes
  - Thinning
  - Residues Removal
  - Clear Cut
- Technique
  - Whole Tree Chips
  - Round Wood
  - Mixed Logs/ Chips

REFOREST

- Method
  - Natural
  - Hand Plant
  - Air Drop
- Wood Type
  - Commercial Quality
  - Energy Quality
- Incentives
  - Federal
  - State

WOODYARD

- Transportation
  - Truck (logs)
  - Trailer (chips)
  - Rail
- Processing
  - Straight Pass
  - Loading/ Unloading
  - Central Chipper
  - Separation
  - Pelletizing
  - Storage
- Contract
  - Loggers
  - Plant Wastes

COMBUSTION

- Fuel Type
  - Green Chips
  - Wood Wastes
  - Pelletized
- Combustor
  - Pinhole Grate
  - Vibrating Grate
  - Travelling Grate
  - Fluidized Bed
- Boiler
  - Fire Tube
  - Water Tube

USE

- Output
  - Steam
  - Electricity
  - Cogeneration (steam and Electricity)
  - Direct Heat
- Society Benefit
  - Environmental Protection
  - Jobs Creation
  - Wood Markets
  - Greater Energy Independence

Figure 1.- Wood Energy Parameters.

IMPACT OF NOVEL ENERGY SOURCES - OTEC, WIND, GEOTHERMAL, BIOMASS

A. Sidney Roberts, Jr.
Old Dominion University

SUMMARY

Alternate energy conversion methods such as ocean thermal energy conversion (OTEC), wind power, geothermal wells and biomass conversion are being explored, and re-examined in some cases, for commercial viability. At a time when United States fossil fuel and uranium resources are found to be insufficient to supply national needs into the twenty-first century, it is essential to broaden the base of feasible energy conversion technologies. The motivations for development of these four alternative energy forms are established in this paper. Primary technical aspects of OTEC, wind, geothermal and biomass energy conversion systems are described along with a discussion of relative advantages and disadvantages of the concepts. Finally, the sentiment is voiced that each of the four systems should be developed to the prototype stage and employed in the region of the country and in the sector of economy which is complimentary to the form of system output.

INTRODUCTION

Few topics in the decade of the seventies stir imagination, inspire awe or provoke apprehension for the unknown among the general public and experts alike as does the energy supply and demand issue. There is wide spread incredulity for the suggestion that within our complex technocratic society straight-forward and immediate solutions may not exist for the problem of energy resource scarcity and escalating fuel cost. Yet, in a free-market economy scarcity precedes rising cost and these effects have been sufficient to set into motion a national governmental and industrial effort to seek alternative forms of energy supply, substitutional fuels, and to promote amelioration of demand which grew for past decades stimulated by cheap energy supplies. It is widely accepted in energy-intensive industries that a broader range or mix of energy supply sources is vital. Leadership in this direction was taken early by some power utilities which installed hydroelectric and uranium-fired power capacity along with the plants utilizing the conventional (and now costly) fossil fuels.

Substitution among non-renewable fossil fuel (and uranium) primary resources, however, will not satisfy the needs of even a modestly growing economy into the twenty-first century. The energy/economic growth issue is widely debated and was soberly discussed with the publishing, in 1974, of the

Energy Policy Project report of the Ford Foundation, entitled, "A Time to Choose" (ref. 1). The nation is faced with an enormous and growing appetite for liquid and gaseous fuels for transportation and industrial processes, for hydrocarbon feedstocks required in chemical processes, and with the need for energy in the highly versatile form of electric kilowatt-hours. Thus, it is that with a quickening pace research and development, efforts turn toward the renewable energy sources, those based on solar, geothermal energy, and the oceans to seek alternative methods to power our high technology society.

The intent of this paper is to survey four alternative energy conversion schemes which have the potential for reducing the demands made on the non-renewable energy sources. Three of these methods are driven basically by the sun's radiate energy and include ocean thermal energy conversion (OTEC), atmospheric winds, and biomass conversion to fuel or feedstock. The geothermal alternative derives from geologic formations of volcanic rocks and heated water deposits naturally occurring in seismically active regions of the earth's crust. As these four alternative energy conversion methods are defined, it is well to bear in mind that collectively they represent no panacea for long-term energy resource ills. Hubbert (ref. 2) has estimated that fully exploited world-wide geothermal sources might supply between 2 and 20% of the ultimate potential of water power, (hydroelectric); and this potential water power, when fully developed, would amount to some 3×10^{12} watts which is only the magnitude of the world's *present* rate of industrial power consumption. Also, a recent report by C. C. Burwell of Oak Ridge National Laboratory (ref. 3) argues that, "all biomass activities in the United States for food, fiber and wood production, if used directly for energy production, might suffice for 25% of the nation's annual energy needs." These figures are presented in order to place in perspective the role of the four alternate energy conversion schemes discussed in this paper. Although there is little hope for one or more of these methods supplanting the energy supply now met via oil and natural gas, which accounts for 75% of the United States energy budget, it is nevertheless essential that research and development efforts aimed at the alternate forms continue at an accelerating rate. While oil and natural gas have dominated the United States energy budget since the mid-nineteen thirties, it becomes more and more evident that the transition period for changing fuel forms, which has been entered, will be one leading toward a varied mix of energy sources by the year two thousand.

A rational national energy policy must ultimately have as a goal the sorting out of emerging energy conversion technologies, phasing them in terms of technical and economic feasibility. "Old" but improving technology, such as wind power generators, will wait in the wings for commercial utilization until curves of decreasing cost of application versus time cross those rising curves of conventional fuel cost versus time. Commercial utilization of specific energy conversion methods has a strong regional dependence in the United States based on climate, energy demand patterns, and availability of energy resources.

Regional Influences

Before discussing the characteristics of the four energy conversion methods, which are the subject of this paper, it is useful to consider some regional patterns of energy supply and demand with particular relation to the southeastern United States. In spite of the desirability for having a mix of primary fuel inputs to the energy supply system of a state or region, local economic conditions and the natural resource base often dictate use of primary fuels; there is no reason to believe that novel energy conversion techniques will be immune to these regional conditions. In a recent report (ref. 4) entitled, "Energy Conditions in the South", the author surveys statistical data for energy supply and demand in fourteen southern states. This region which included Texas and Oklahoma produced in 1972, 73% of the nation's domestic energy budget while comprising less than 29% of the population.

The regional demand pattern for these fourteen southern states is interesting. Some effects of the industrial mix and complexion of the general consuming public are demonstrated in table I taken from reference 4. States such as Louisiana, Texas, and West Virginia rank high in per capita annual energy usage largely because their energy producing industries (fossil fuels) are very energy intensive.

The need for growth in national electricity production is well documented (see for example ref. 5). The South, too, expects growth in this supply sector to maintain economic viability. In this regard, and with particular reference to the development of the alternate energy conversion methods, it is useful to examine criteria used to determine sites for new electric power plants. Figure 1 demonstrates suitability of plant site selection in the southeast United States. For reasons which will be discussed, it is important to note that offshore regions in the Gulf of Mexico and southeastern Florida coast have been identified as likely sites for OTEC plants. Although these oceanic sites do not match electrical load centers in the southeast, it is feasible to convert electrical energy in large quantities to chemical products (fuels and feedstocks) which become more transportable to supply inland markets.

In the remainder of the paper the four alternate energy conversion methods will be treated successively. By defining the physical nature of the energy conversion methods and from an assessment of relative advantages and disadvantages some tentative conclusions can be drawn as to the role which the alternative energy schemes may play in meeting future energy demands in the southeastern United States.

OCEAN THERMAL ENERGY CONVERSION

The OTEC system operates as a thermodynamic heat engine driven by energy flow between a heat source and sink which are the warm surface waters and the cold deep sea waters common to semi-tropical regions. The sun, of course, assures a constant supply of warm surface conditions in the oceans so that OTEC plants would operate around the clock (capacity factor approaching 100%). Large volumes of sea water must be passed through the plant with the cold stream being drawn from a depth of some 250 to 300 meters. Operating between the limiting temperatures, the ideal plant efficiency, η, (ratio of useful work output to thermal energy input) is,

$$\eta = 1 - \frac{T_D}{T_S} \qquad (1)$$

If the deep sea temperature is 283 K and the surface temperature is 301 K, the ideal efficiency is, $\eta = 6\%$. Because of nonideal processes, actual OTEC plant efficiencies are likely to range 1 to 3%. The efficiency of conversion is really of little consequence since the energy input is "free" (except for the cost of operating pumps).

The schematic diagram shown in figure 2 outlines the thermodynamic cycle for OTEC. A working fluid such as ammonia or propane, having a low temperature boiling point, is evaporated by heat from warm sea water, it expands through a turbine, produces electricity, and rejects heat in a condenser to the cold sea water. Plant outputs of several hundred megawatts of electricity are envisaged (see ref. 6). Other engineering questions that need addressing are considerations of plant siting and environmental impact, costs of constructing, deploying and maintaining the plants, and the form of the energy output and nature of the product markets.

Plant sites are generally limited to deep, offshore regions where a temperature difference of 15 - 20 degrees Celsius can be achieved. Stationkeeping mooring systems must be used for the floating OTEC plants. Tropical storms pose a hazard and the plants themselves should not menace transport in shipping lanes. Potential plant sites are suggested in figure 3 demonstrating proximity of sites to the Southeastern United States. Besides the normal waste management question for a manned OTEC plant, the most significant environmental issue pertains to the vast quantities of cool water brought to and dispersed on the surface downstream from the plants. It is argued in reference 7 that the sea surface temperature depression should approximate .5°C. The environmental impact issue will need continuing study.

Because OTEC plants are ship-like, it is expected that existing maritime practice and ocean/marine engineering technology will apply allowing realistic cost estimates for the floating plants. Some extension of engineering design and technology is needed for the long cold water suction column extending beneath the plant and for the large heat exchangers required for the evaporator and condenser units. Biofouling of the seawater tubes (perhaps 2.5 cm in diameter) is proving to be a major problem. Current thinking suggests that a continuous method of mechanical removal of the slime will be required (see reference 8). Cost estimates for plant construction on the basis of dollars per installed kilowatts are found to be larger than comparable land-based coal or uranium fired power plants. However, since OTEC costs include no fuel charges, it is fair to say that capital costs of OTEC plants can be 25 to 50% higher than land-based plants with similar power output ratings and still remain competitive. Firm cost estimates must await a successful commercial demonstration.

The energy product of OTEC plants may prove most economically viable when on-board energy is used to produce valuable chemicals. On-board processing has been studied for cost effectiveness; potential products include methane and methanol from processed coal, ammonia for fertilizer, hydrogen as stored energy and certain plastics. So, electric power may not be cabled to shore, but rather OTEC plants can be designed as chemical complexes to serve land-based markets. Optimal sites for the chemical OTEC complex are in fact located in tropic zones of the Atlantic and Pacific oceans.

The advantages of the OTEC concept include continuous plant operation, no fuel cost, large energy resource without land-use problems, deployable, modular systems taking advantage of maritime/shipbuilding technology, and adaptability as chemical factory ships.

Also associated with OTEC are disadvantages such as heat exchanger/cold water pipe problems, susceptibility to damage from tropical storms, high initial cost of a demonstration plant which would attract commercial interests, unresolved environmental, legal, and indemnity issues, disincentives of capital risks preventing expenditure of necessary amounts of industrial research and development money.

WIND POWER

The Persians built the first known windmills as early as 250 B.C. This power source along with geothermal and biomass conversion represents a revisitation of technology which evolved hundreds of years ago. Significantly, however, twentieth century science and engineering is being applied to the old concepts. Instead of turning a millstone to grind grain, the modern windmill more likely will turn a sophisticated synchronous generator which can provide 10 to 1,000 kilowatts of electric power, operating through low friction bearings, and taking advantage of space-age aerodynamics and new materials. Still, it will be difficult for the wind-powered machine to compete economically with conventional sources of electric power, except perhaps in remote regions where conventional fuels are quite costly and electricity is not available.

The historical perspective for wind generators has been described by numerous authors. Interesting recent presentations include those listed as references 8, 9, and 10. The most pertinent aspect of the historical perspective is to be guided by past successes and failures toward designs which in a modern context will have high probability for technical and economic success. For electric power production the economies of scale have apparently urged the U. S. Department of Energy toward a development program intended to demonstrate the feasibility of machines producing 100 to 10,000 kilowatts of electricity to couple with existing electric power grids; however, smaller machines are not altogether neglected. In this context two classes of machines are under active development: the up-wind or down-wind horizontal axis machine and the vertical axis Darrieus windmill; these two types are displayed schematically in Figure 4. Both machines are able to convert to useful work a significant fraction of the kinetic energy of a wind stream volume passing through the area swept by the windmill blades. The delivered power, P, may be expressed as

$$P = C_p \ 1/2 \ \rho A v^3 \qquad (2)$$

where v is the wind speed, A is the area swept by the blades, ρ is the air density and C_p is known as the power coefficient, a number less than 0.6. The Darrieus and two-bladed horizontal axis machines sketched in figure 4 have higher values of C_p than traditional Dutch or farm-type machines, values approaching .35 and .47, respectively. To convert the wind energy to electricity the blade rotor is either coupled to a variable speed, constant-frequency generating system or is operated at constant speed while changing the blade pitch in a varying wind. The 100 kW prototype machine near Sandusky, Ohio, (the first windmill built by NASA/DOE) operates with the latter wind rotor design.

To achieve significant annual power production, high performance windmills must be located in areas of steady and relatively high speed winds. Candidate sites can be located by delineating geographical areas where average wind speed at 45.7 meters (150 feet) altitude above ground level equals or exceeds 8.0 meters per second (18 miles per hour). Such areas in the contiguous United States include essentially regions of the western Great Plains, the Atlantic seacoast (above latitude 35° North) and the Appalachian mountains. In reality, the winds are variable in both speed and direction; surface contour and roughness are added factors weighed in the site selection process. As a design goal for windmill power, engineers seek to generate useful power whenever there is sufficient wind to activate the machine; this suggests the need for energy storage capacity. The ability to utilize wind power when available can be provided by coupling the wind generators directly into existing electric utility grids; this is currently being accomplished with Department of Energy demonstration projects.

As mentioned above, the first demonstration machine (down-wind, horizontal axis type) near Sandusky, Ohio, is supplying electric power to the NASA Plum Brook Station. A similar 200 kW wind turbine is now operating in Clayton, New Mexico. Of particular interest to the Southeastern states is another DOE demonstration wind machine to be located on a mountaintop near Boone, North Carolina. This 2000 kW machine will permit the Blue Ridge Electrical Membership Corporation to decrease the power it now buys from a private power utility.

The cost of windmills on the basis of dollars per kilowatt of installed capacity remains high when compared with conventional electric power systems. The situation will grow more competitive as fossil fuel cost rises and as the unit cost of wind machines decreases when size of windmills increases and mass-production techniques are introduced. A cost scenario is depicted in figure 5 (taken from ref. 9) where wind turbine selling price is graphed against wind turbine size. This projection can be contrasted to the cost of conventional systems where unit costs range between 100 and 1000 dollars per kilowatt.

GEOTHERMAL POWER

The surface manifestations of geothermal energy deposits are the naturally occuring wet and dry steam plumes which occurring over certain regions of the earth's surface. These deposits of earth-heated water and steam are found in areas of recent volcanic activity and are located in zones coinciding with the margins of active tectonic plate boundaries. Basically, geothermal sources can be classified in four categories, (a) vapor-dominated (dry steam), (b) liquid-dominated (superheated water and brine), (c) geopressurized reservoirs, and (d) hot dry rocks. Sources (a) and (b) have been utilized for centuries for comfort heating and cottage industry; electricity was first produced from a geothermal dry stream source in Larderello, Italy, in 1904. Geothermal power converted to electricity amounted to 1172 megawatts, worldwide, in 1975. The Geysers in Sonoma County, California, accounted for 516 megawatts of this productivity (ref. 11). Interestingly, greater than 50 percent of worldwide geothermal source utilization is used for district heating and other non-electrical applications. Although this alternate energy source is already economically competitive for electric power production in those regions where wet and dry steam deposits are found, a significant contribution to electric power needs should not be anticipated until the vastly more abundant sources (c) and (d) can be exploited.

Geopressurized reservoirs such as those found under the coast of the Gulf of Mexico, from Mexico to Mississippi, contain hot water (150 to 180°C) at pressures of 30.4 meganewtons per square meter (300 atmospheres, ref. 12). Also contained in these deposits is a significant concentration of dissolved methane. Utilization of this resource hinges on development of deep drilling technology and the resolution of environmental impact questions the foremost of which is the issue of land subsidence.

Deep hot rock formations of high porosity are abundantly found beneath the levels penetrated by underground water systems. The Los Alamos Scientific Laboratory is engaged in experiments where holes are drilled into the hot impermeable region and hydraulic fracturing techniques are used to create a large surface area reservoir (ref. 12). Pressurized water may be injected into the reservoir where it is heated and is then returned to the surface through another well penetration. These experiments lead toward knowledge of fracture size and orientation, information which is needed for engineering design studies which precede plant construction and the ultimate economic utilization of this geothermal source.

The wet steam and hot brine wells pose difficult engineering problems for applications where electric power is produced by expansion of working fluids through a spinning turbine. Advancements have reached a point, though, where technical information has been organized in text book form for geothermal engineers, this recently accomplished by Edward Wahl (ref. 13). Utilization of the liquid-dominated geothermal source requires plant components for flash-evaporation and steam separation in several stages. The equipment, while available, is costly and difficult to maintain with constant exposure to mineral-rich geothermal well water due to scaling and corrosion problems. Source temperatures for this plant-type must be approximately 100°C or greater to yield practical plant efficiencies. Liquid-dominated wells have been observed in the Imperial Valley of California with temperatures up to 300°C (ref. 11). An average production well in a hot water field is drilled to 914 meters (3000 ft.) at a cost, in 1975, of $150,000. Tester and Milora (ref. 12) have noted that well drilling and casing costs typically comprise 40 to 80 percent of the total capital investment in a geothermal power plant, a point which will be re-emphasized in a subsequent paragraph.

There have been advancements in thermodynamic cycles useful in geothermal plants with particular relation to the more abundant liquid-dominated and hot brine sources. Scaling and corrosion problems will continue to plague design engineers, but improved cycles increase plant efficiencies and lower power generating costs. The binary fluid cycles offer thermodynamic advantages; the geothermal source exchanges heat with a working fluid which is evaporated and then caused to expand through a turbine. Working fluids such as ammonia and isobutane are being considered for dual and staged cycle configurations. Prototype turbines are being constructed for an experimental plant in the Imperial Valley of California, while a Russian geothermal power plant with binary fluid cycle is operating on the Kamchatka Peninsula producing 440 KW from 80°C well water (ref. 11).

The work by Tester and Milora (ref. 12) presents a careful analysis of plant economics pointing out controlling effects such as well flow rates, fluid temperatures and natural geothermal gradients (temperature difference per unit depth into earth). They also show that for a given set of resource and power plant conditions there is an optimum depth for drilling. Their results were generalized to form a cost model expressed parametrically as a function of well flow rate, fluid temperature and geothermal gradient using a binary fluid cycle. One such result is displayed as figure 6, where total generating cost is plotted against geothermal fluid temperature with geothermal gradient as a parameter. Cost estimates, which were thought to be conservative, for direct flashing and binary fluid cycles range 1.56 to 4.30 cents per kilowatt-hour, values which compare favorably with generating costs for fossil fuel-fired and nuclear plants of similar capacity.

BIOMASS CONVERSION

Photosynthesis and plant growth are steps in the indirect process of converting solar energy into another useful form. Once organic plant material develops, in any form from algae to wood, it exhibits per unit of mass a heating value approximately one-half that of better coals. This, then, is the basis for renewed interest in the processes of agricultural and silvicultural (forestry) biomass production. This photosynthetic solar energy conversion mechanism, while not very efficient at 1 to 3%, does have an advantage over direct solar energy collection methods in that the plant growth process intrinsically stores energy in biochemical form for later use, and stores the energy anytime the sun shines. Most often biomass conversion is identified as a process of growing plants for fuel or for conversion to a chemical feedstock. However, in a broader sense biomass conversion encompasses the utilization of biomass residues in the form of urban and municipal wastes, animal wastes, and residues from industrial, agri- and silvicultural processes. The following paragraphs place this energy resource in perspective.

The new aspect of biomass conversion centers on the assessments, mostly economic, which seek to show whether or not advanced growing and processing techniques can provide a high yield fuel crop with a high energy output to input ratio. High yield crops such as corn, sorghum and sugar cane are known, but it is doubtful that they can or should be cultivated for their energy content. Many advocates believe that large scale energy plantations, or tree farms, will demonstrate competitive costs per unit of energy delivered (references 14, 15), although this concept runs head-long into land ownership and use questions. Recently, Ronald Wishart of the Union Carbide Corporation has written (ref. 16) that certain fermentable sugars and cellulose-rich products can already be produced in quantities that match the feedstock needs for some chemical products such as ethylene. It appears that the chemical industry wishes to be prepared with biomass processing technology when markets begin to develop for fuel products such as ethanol and methanol.

The open question of whether or not to centralize biomass for fuel projects into energy plantations incorporating growing, gathering, and power plant operations is receiving much attention. The more appropriate technology may be a dispersed biomass productive capacity; Dr. Newton Rose, a geographer at Old Dominion University has addressed this issue with particular reference to the Southeastern United States in a recent unpublished paper:

> "In the Southeastern United States biomass conversion may have more chance of success on a much smaller scale than that envisioned by the proponents of the plantation concept. Direct burning of biomass materials or conversion to other forms of fuel in units on farms or at mills scattered through the rural landscape may be more appropriate for this technology."

C. C. Burwell of Oak Ridge National Laboratory has attempted to estimate net available United States biomass energy resources in a previously referenced paper (ref. 3). A summary is shown in tables II and III in terms of energy yield aggregated for all agri- and silvicultural production and residuals. In table II net production is shown where allowance is made for required energy inputs for crop production; collectable net energy yield is shown as 17.2×10^{15}Btu(18.1×10^{18}joules). Table III shows contributions from non-agricultural residues and uncollected residuals; these are 3×10^{15}Btu(3.2×10^{18} joules) and 5×10^{15}Btu(5.3×10^{18}joules). If the biomass energy resource is accumulated in terms of net energy potential of crops (all going for fuel) with the available residuals, the sum is

$$(17.2 + 3 + 5)10^{15}\text{Btu} = 25.2 \times 10^{15}\text{Btu}(26.6 \times 10^{18}\text{joules}). \qquad (3)$$

Of course, the largest part of current biomass production goes to supply food and fiber. The point of this analysis is to emphasize that the current net available biomass energy resource of some 25×10^{15}Btu(26×10^{18}joules) amounts to only 1/3 to 1/4 of the energy used per year in the United States.

The relative abundance of arable land in the United States engages the attention of thoughtful energy managers and encourages research aimed at development of fuel crops. These materials represent a renewable fuel source the burning of which presents few additional clean-up problems relative to the fossil fuels. Still, the strongest argument against plants for fuel relates to the competition for land use. Land must be employed for production of food and fiber, for watersheds, for habitation and recreation. The direct conversion of solar radiation to heat and electricity is also more efficient than photosynthesis by a factor of 20 or 30. As with the other alternate energy conversion methods discussed here, biomass conversion will undoubtedly be utilized, first in the form of demonstration projects (DOE is currently negotiating a wood-power design project in Maine), and then under circumstances where economic analysis shows that biomass power is a competitive supplementary energy resource.

CONCLUDING REMARKS

Certainly the United States should develop the technical, social, and political capability and willingness to employ these alternate energy forms. The government will stimulate research and development activity providing some incentives for industry; yet, ultimately the innovators and leaders working in the marketplace must set the course toward commercialization of the OTEC, wind, geothermal, and biomass energy systems. To the extent that government, industry, and others in the scientific and engineering communities join more firmly in partnership, then will these technologies be made available to the people when and where they are needed.

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TABLE I. RANKING OF STATES IN TERMS OF ENERGY USAGE PER CAPITA

	Population (thousands)	Per Capita Usage 10^6 Btu/yr	United States rank
Louisiana	3,738	716	2
Texas	11,604	589	4
West Virginia	1,795	633	5
Alabama	3,521	414	11
Oklahoma	2,633	390	12
Arkansas	2,008	325	14
Mississippi	2,256	305	19
Kentucky	3,306	382	27
Tennessee	4,072	316	31
Georgia	4,733	290	35
Virginia	4,765	254	39
South Carolina	2,688	273	41
North Carolina	5,221	268	45
Florida	7,347	217	50

TABLE II. POTENTIALLY COLLECTABLE NET YIELD FROM U.S. BIOMASS OPERATIONS UNDER PRESENT MANAGEMENT PRACTICES (1974)

Activity	Gross Energy Yield, 10^{15} Btu	Collectable Net Energy Yield,[a] 10^{15} Btu
Agriculture		
Corn	3.9 (1.9)[b]	3.0 (1.8)
Grains	3.2 (2.1)	2.9 (2.0)
Green Crops	2.2	2.1
Oil Seeds	1.2 (0.4)	1.1 (0.4)
Fruits & Veg.	0.2	0.2
Other	0.7	0.6
Silviculture	9.3 (3.7)	6.6 (1.2)
Pasture and Range	7.0	0.7
	27.7 (8.1)	17.2 (5.4)

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[a] Petroleum energy inputs valued at 1.5 times the value of biomass energy.

[b] Residue values given in parentheses.

TABLE III. MAJOR SOURCES OF BIOMASS RESIDUES

Collected	Million Dry Tons	Energy,[a] 10^{15} Btu
Urban & municipal solid wastes	160	2.1
Large poultry & hog operations & cattle feedlots	26	0.3
Large canneries, mills, slaughter houses, & dairies	23	0.3
Wood manufacturing	15 to 27	0.4
	∿230	∿3
Uncollected		
Cereal straw, cornstalk and logging residues	∿365	∿5

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[a] Residues evaluated at 13 MBtu/dry ton except for wood residues at 17 MBtu/dry ton.

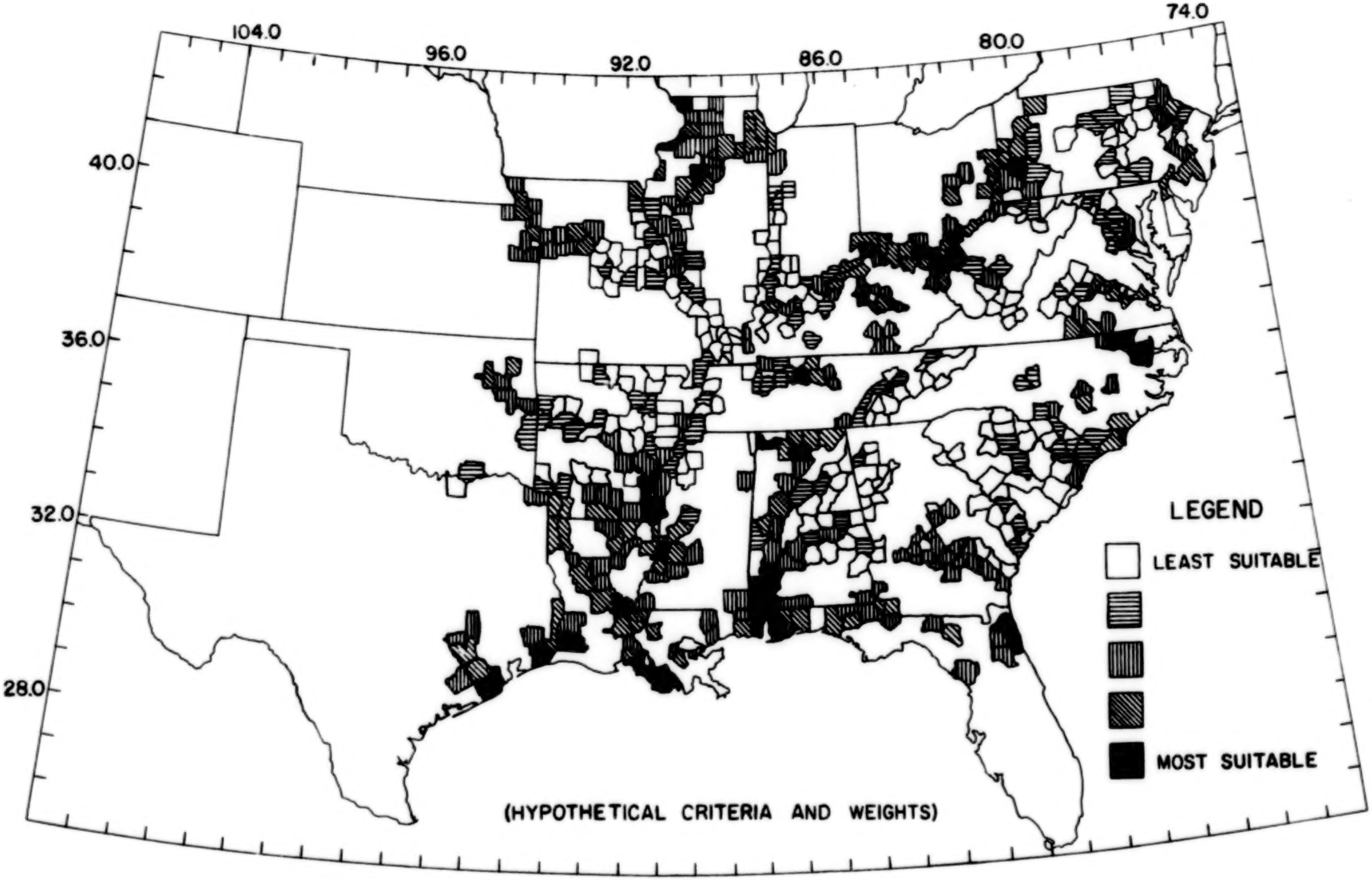
104.0
96.0
92.0
86.0
80.0
74.0
40.0
36.0
32.0
28.0
LEGEND
LEAST SUITABLE
MOST SUITABLE
(HYPOTHETICAL CRITERIA AND WEIGHTS)

Figure 1.- Suitability of sites for central electric power stations.

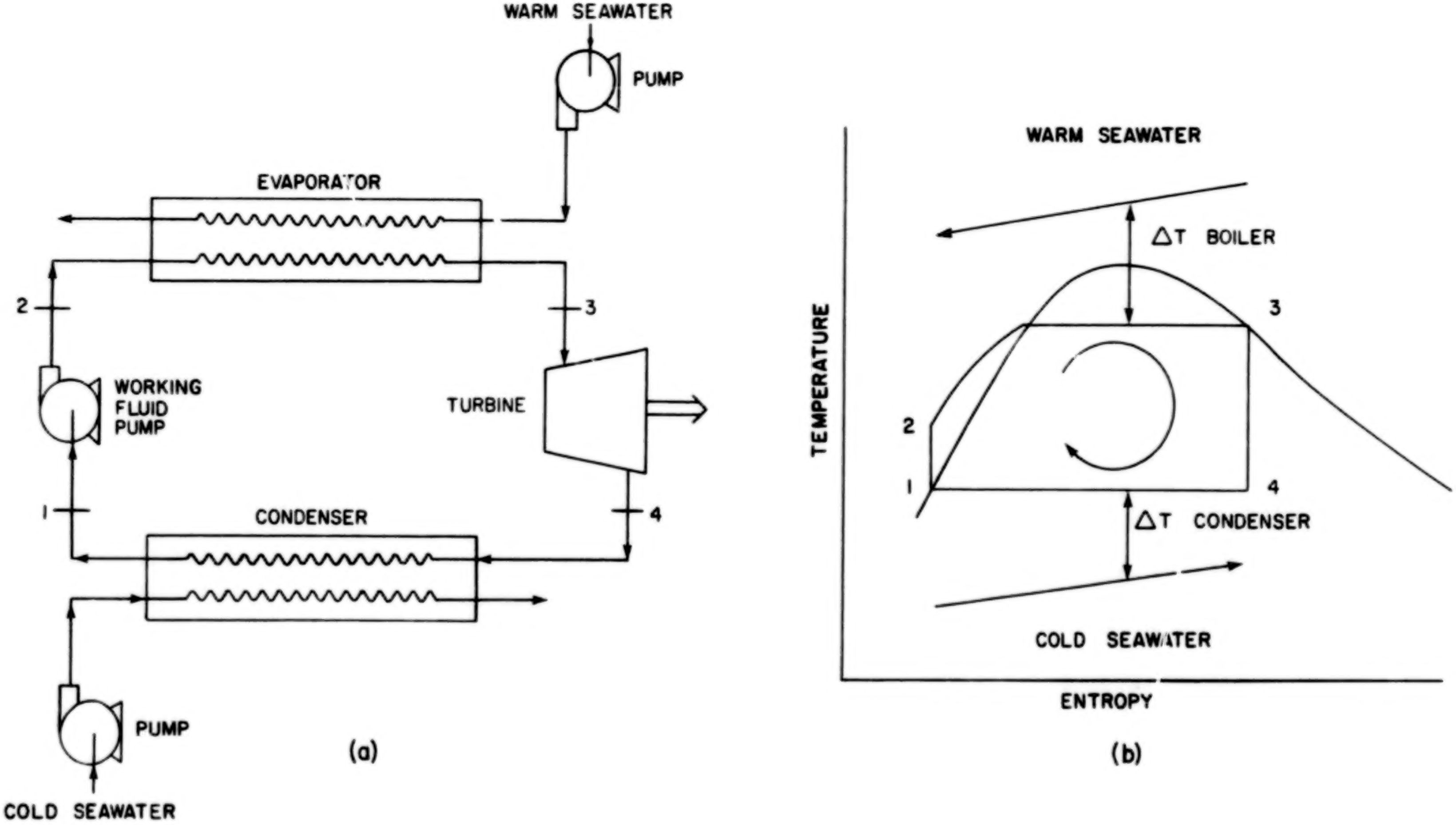
WARM SEAWATER
PUMP
EVAPORATOR
2
3
WORKING FLUID PUMP
TURBINE
1
4
CONDENSER
PUMP
COLD SEAWATER
(a)
WARM SEAWATER
ΔT BOILER
TEMPERATURE
3
2
1
4
ΔT CONDENSER
COLD SEAWATER
ENTROPY
(b)

Figure 2.- Typical binary fluid cycle for OTEC (a) and temperature-entropy diagram (b).

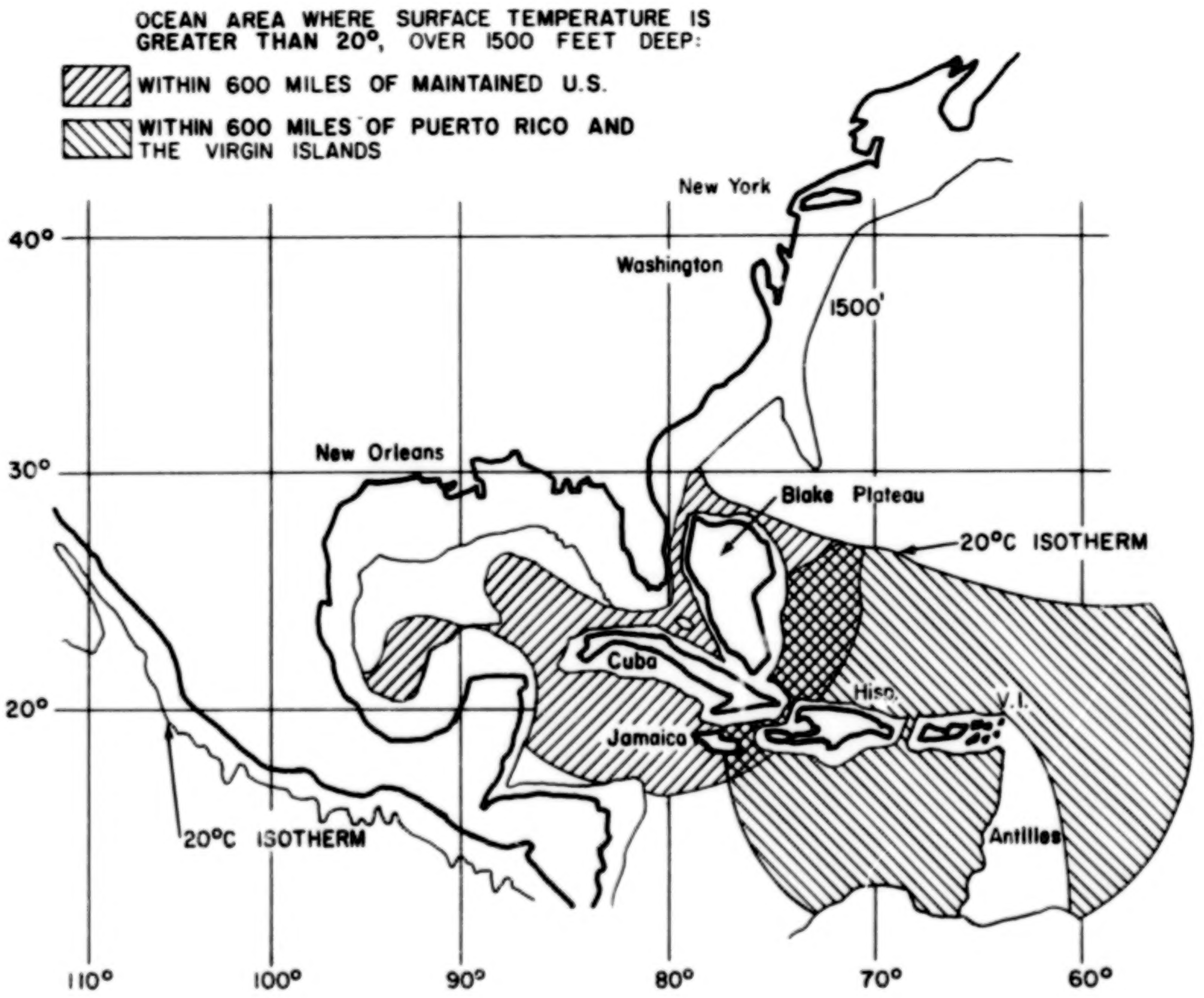
OCEAN AREA WHERE SURFACE TEMPERATURE IS GREATER THAN 20°, OVER 1500 FEET DEEP:
▨ WITHIN 600 MILES OF MAINTAINED U.S.
▨ WITHIN 600 MILES OF PUERTO RICO AND THE VIRGIN ISLANDS
New York
Washington
1500'
New Orleans
Blake Plateau
20°C ISOTHERM
Cuba
Hisp.
V.I.
Jamaica
Antilles
20°C ISOTHERM
40°
30°
20°
110°
100°
90°
80°
70°
60°

Figure 3.- Feasible coastal sites for OTEC plants.

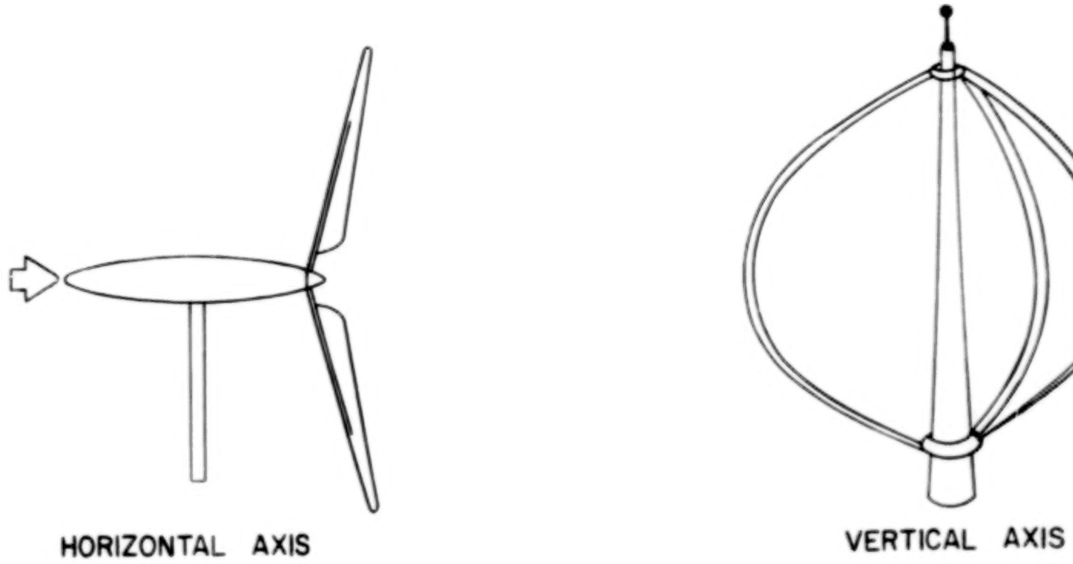
HORIZONTAL AXIS
VERTICAL AXIS

Figure 4.- High performance windmills.

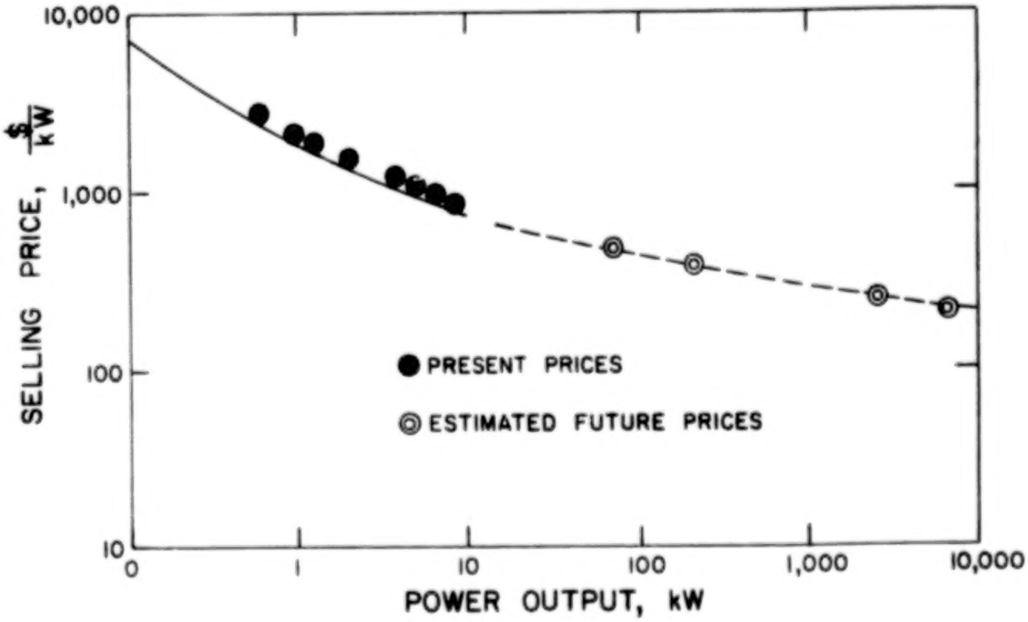

Figure 5.- Projection of installed price
for windmill electricity.

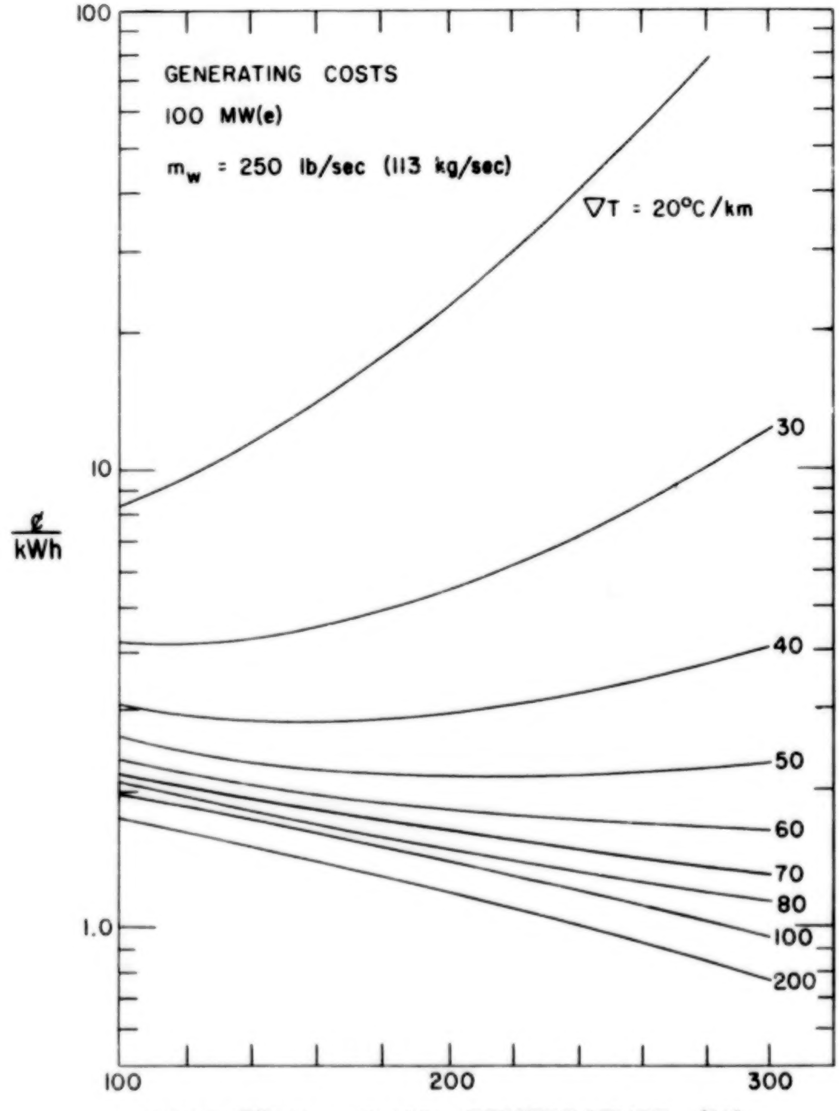

Figure 6.- Generating costs for a binary fluid geothermal plant.

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AGRICULTURAL AND INDUSTRIAL PROCESS HEAT

James Dollard
Agricultural and Industrial Process Heat Branch
Office of Solar Applications, Department of Energy

INTRODUCTION

The U.S. Energy Problem

The projected U.S. demand for natural gas and petroleum through the year 2000 exceeds our domestic supply, making our nation's economy dependent upon uncertain imports. Estimated future production of these fossil fuels is given in figures 1 and 2. Crude oil imports now represent more than half of the total U.S. petroleum consumption. In addition, U.S. petroleum consumption is larger today than it was before the OPEC embargo began in October 1973. Both oil and natural gas prices have increased greatly since 1973, and these price increases have spread throughout the economy, adding to inflationary pressures.

The U.S. Response

The U.S. has adopted a mixed set of both near-term and long-term strategies in response to increasing fuel prices, the threat of future embargoes, and the diminishing supply of fossil fuels within the United States. Near-term efforts include energy conservation, the establishment of strategic oil reserves, an effort to double coal production by 1985, and a reduction in the licensing time necessary for nuclear power plant construction. Long-term strategies include the exploitation of oil shale and tar sands resources as well as the development and commercialization of renewable energy resources such as solar energy, geothermal and fusion power.

The topic of this discussion is one element of this overall effort; the application of solar energy to agricultural and industrial process heat requirements. This energy end use sector has been the largest (ref. 1), and it appears that solar energy can, when fully developed and commercialized, displace from three to eight or more quads of oil and natural gas in U.S. industry. This potential for fossil fuel displacement in the agricultural and industrial process heat area sector represents a possible savings of 1.4 to 3.8 million barrels of oil daily.

Alternative Energy Technologies

The alternative or renewable energy technologies being developed and commercialized by DOE include the following:

1. Solar thermal technology
    a. Low temperature flat plate solar collectors for heating
    b. Intermediate temperature concentrating collectors for process heat applications
    c. High temperature concentrating and heliostat - furnace solar thermal systems for the generation of electricity;
2. Solar photovoltaic technology for the direct conversion of solar radiation to electricity with or without solar radiation concentrators;
3. Wind machines for conversion of this form of solar energy to mechanical energy for pumping water, and/or the generation of electricity;
4. OTEC - Ocean Thermal Energy Conversion; the surface water of the ocean is a natural collector of solar energy, and surface to deep water temperature differences can be effectively utilized to generate electricity, and in turn hydrogen through electrolysis;
5. Biomass in which plants, trees and other crops are used as a fuel through direct burning or are converted into methane and other gases for use as fuels and similar related conversion processes;
6. Geothermal energy, wherein the energy from the molten core of the Earth heats water turning it into steam which in turn can be used to generate mechanical and electrical energy, through normal conversion processes.

DOE is also developing safe, nuclear power systems to provide electrical energy. The low temperature waste or rejected heat from these power plants can be used in some agricultural and industrial processes, which are located within a reasonable distance, one or two miles, of the nuclear reactor.

AGRICULTURAL AND INDUSTRIAL PROCESS HEAT ENERGY REQUIREMENTS

Total United States energy demand decreased from 1973 through 1975 as shown in figure 3. Energy consumption in the mining and manufacturing industries is reported on a preliminary basis to have increased in 1976 but to be below the level required in 1973 (ref. 2). Energy end use by the three major sectors in 1974 is shown in figure 4. Industry consumed 28.4 quads, or 39 percent of the total U.S. consumption of 72.7 quads. Energy consumption in the United States in 1978 has been estimated to be in the range of 78 to 80 quads with a proportionate increase in the industrial sector to a total of about 30 quads.

Agricultural Energy Requirements

Agricultural energy requirements include the five energy requirements shown in figure 5. The temperature spectra of agricultural process heat applications are given in figure 6.

The estimated growth in demand for agricultural process heat is shown in figure 7. It should be noted that by the year 2000 estimates show that solar will be supplying approximately 50 percent of all agricultural process heat applications (ref. 3).

The temperatures required by a number of specific agricultural process heat applications are indicated in figure 8. Note that these temperatures extend through a broad range from about 110°F to 450°F, although higher temperatures are not required for "on the farm" type applications.

The milestones for the DOE solar agricultural process heat program are shown in figure 9 for FY 1977 and FY 1978. The locations of ongoing and completed agricultural process heat projects are shown in figure 10.

Industrial Energy Requirements

Energy requirements in mining and manufacturing industries vary tremendously in magnitude and temperature levels required for processing activities. In 1976, the chemical industry was the largest process heat consumer with the greatest usage in a temperature range between 212°F and 350°F. Within the primary metals industry, most of the consumption took place in blast furnaces for the production of basic steel products. Over 92 percent of this energy usage was at temperatures greater than 550°F. Substantial amounts of this demand were centered in the iron and steel mills in the Birmingham, Alabama area.

Studies to date indicate that the industries which could benefit the greatest from use of solar equipment are those using large quantities of process heat in the range of temperatures below 550°F. A temperature breakout of process heat consumed in 1976 at less than 550°F is given in figure 11. Existing solar technology is capable of meeting a substantial portion of these needs. Research and development is currently underway to examine solar applications in generating higher temperatures at higher pressures for power generation. Over 90 percent of the heat used in the chemical industry in 1976 was at temperatures less than 550°F, making this industry a strong candidate for a high level of solar penetration. Virtually all of the heat consumed in the food industry was in these lower ranges. The food industry represents a large potential for solar applications in view of existing processes such as can washing for sterilization purposes and water heating for clean in place (C.I.P.) equipment where sanitary conditions must be maintained.

Conservation efforts have already been implemented in some industries, such as cane sugar refining, which have led to a complex but energy efficient system of cascading steam and hot condensate sources which address total plant rather than individual process requirements. However, in other industries, such as prepared animal feeds, energy is consumed to produce temperatures which are far in excess of the actual temperature at which the process heat is required. For instance, gas-fired dryers are widely used here in which the gas is cooled to an inlet temperature of 1600°F, much higher than the actual temperature required for drying. Solar equipment could meet these needs at lower temperatures if consideration is given to actual process requirements (ref. 4).

Southeastern states provide much of the nation's paper, textile mills and lumber products. Large contributing metropolitan areas include Greenville-Spartanburg, South Carolina; Charlotte-Gastonia, Greensboro-Winston-Salem-High Point, and Burlington, North Carolina; Memphis and Chattanooga, Tennessee (ref. 5). Much of the energy required for these processes is at lower temperatures, less than 550°F. In textile mills, for instance, these processes include scouring, bleaching, rinsing, and washing. Dyeing procedures vary widely due to fiber content, the dyestuff used, the end use of the product, the available processing equipment, and the process management. The rate of temperature rise and cooling must be carefully controlled along with the volume of the bath.

In 1974, states such as Alabama, Georgia and Florida produced a high volume of paper products and consumed a corresponding amount of energy. Figure 12 shows the rank order of top consuming states in the paper industry that year. Bureau of Census data also indicates that the Southeast contained the nation's top three energy consuming states in the textile industry - North Carolina, South Carolina, and Georgia, as shown in figure 13. Another major industry in this region is lumber and wood products, which was next only to the Far West in consumption that year. The national rank order is given in figure 14.

FOSSIL FUEL AND ELECTRICITY PRICES

In the industrial sector the quantity of electricity purchased for process heat generation is greatly disproportionate to fossil fuel use for this purpose. As shown in figure 15, by 1985 it is expected that solar can become competitive if life-cycle costs can be reduced to within two times projected natural gas prices which are presently increasing rapidly. In the long term it is expected that there will be a large price difference between coal and natural gas, with gas moving into a range comparable to petroleum products. An investment in solar equipment by 1985 will amortize over the operational lifetime with increased fuel savings.

State Breakdown

Analysis of Bureau of Census data for 1974 indicated that the highest industrial gas rates existed in Northeastern and New England areas, where there has also been the greatest distribution scarcity. The data is shown graphically in figure 16. Within the Southeastern region, the highest gas rates were in North Carolina, South Carolina, Georgia, and Florida.

Distillate oil prices for manufacturing industries were among the nation's highest in South Carolina that year, as shown in figure 17. As with natural gas, there has been a strong price difference within the Southeastern region between the easternmost states and neighboring states of Mississippi, Tennessee, and Kentucky for electricity. Figure 18 illustrates these state averaged rates for 1974.

KEY PROBLEMS FACING "SOLARIZATION"

At the present time the cost of solar systems is too expensive to be competitive with fossil fuels for many agricultural and industrial applications. Only by greatly reducing the cost of manufacturing, installing, checking out and providing continuing service and maintenance of solar systems can cost competitiveness be achieved in the market place. Such cost reductions must occur if solar is to have a significant role in the American energy supply. Some of us believe that such cost reductions can be achieved through the vigorous and aggressive application of the American genius for low cost mass production that has given our country its high standard of living. We believe that the production expertise exists which can be adapted in order to bring solar equipment costs down to a level competitive with fossil fuels.

Large agricultural and industrial facilities enjoy the least expensive fossil fuel rates in the business world. However, these fuel rates vary widely from area to area and from state to state as discussed previously. Industry will use solar energy only if it can become an economically competitive, reliable alternate to increasingly scarce fossil fuels.

Agricultural and industrial process heat applications are much more varied and numerous than residential or commercial heating and cooling applications. This variation allows a wide range of possible solar energy markets for direct solar process heating and/or preheating. However, this variation also makes identification of potential solar applications and market targets more complex. In perspective, though, the technical problems are relatively insignificant when compared to the cost reduction problems for solar industrial and agricultural systems. It seems that solar agricultural applications at this time are probably more economically competitive than industrial applications for several reasons:

1) "on the farm" solar applications can be built simply and effectively by the farmer himself - thereby greatly reducing their cash costs.

2) a larger percentage of agricultural applications utilize lower temperature heat, where solar energy systems can be simpler and less expensive.

Industrial applications for solar energy are greatly varied in both heat quantity and quality requirements. For higher temperature systems, not only will collector costs need to be reduced but also systems interface and structural costs will need to be significantly reduced for solar to compete with oil and natural gas. However, preliminary studies of the potential for such cost reduction indicates that such reductions seem feasible through the wise application of U.S. automated mass production techniques.

COST REDUCTION THROUGH MASS PRODUCTION

At the present time solar systems are virtually hand made and use low production rate methods which involve the use of hand tools and only a few very simple tools and jigs to reduce the labor costs of production. Labor costs are quite high as compared to what could be achieved with automated mass production methods as found in many American factories such as automobile factories. Material costs are relatively high for flat plate collectors, but this is not the case for concentrating collectors which use metallic reflectors at relatively low concentrations of sixty to eighty suns.

Mass production with automated high production rate techniques together with new installation systems and techniques have the capability of significantly reducing collector costs so that solar systems can compete with oil and natural gas. The lower solar system curve in figure 19 indicates the cost reduction that some believe can be achieved with a combination of mass production and federal incentives.

System costs can be improved through the following:

1) Standardization - mass production of modular, easily installed, easily integrated sub-systems.

2) Optimization of system design utilizing standardized and modular solar energy components which can be combined, depending upon the application, into cost-effective systems.

3) Careful integration of the baseline or reference solar system designs into individual industry applications utilizing optimum thermodynamic and energy conserving design techniques so as to produce integrated and highly cost-effective solar systems with mass-produced, modular sub-systems and components. In this way, solar will have the benefits of low costs that come from high rate mass production techniques, and yet the modular designs will be tailored to each agricultural and industrial solar applications.

CONCLUDING REMARKS

Great opportunities exist for solar energy to be used extensively in the Southeastern states in the paper, textile, lumber, and other industries. Solar energy is expected to reach a price range competitive with oil and natural gas in the early to mid Eighties through the economies of mass production and the benefits of a mix of Federal incentives.

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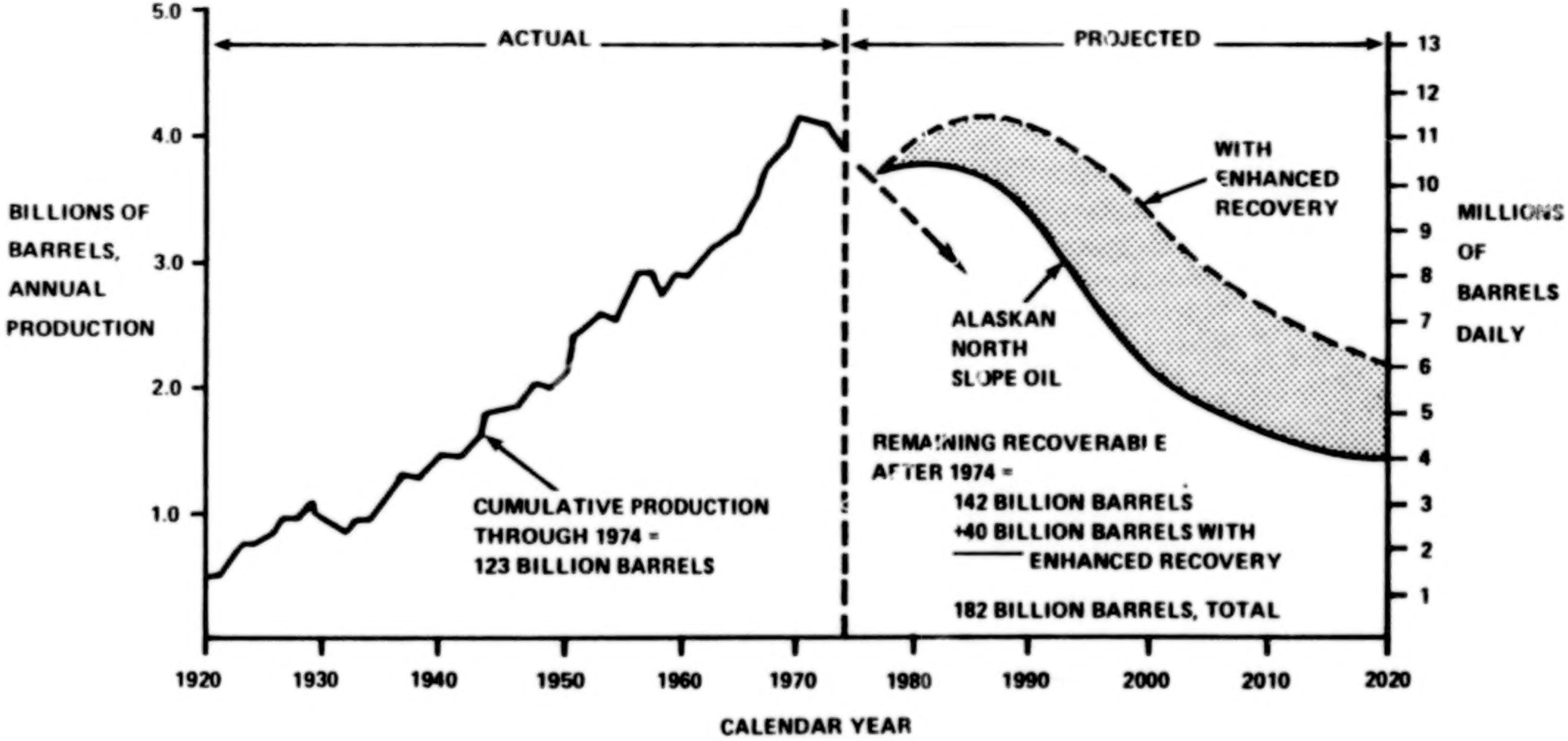


IN THIS FIGURE, DOMESTIC OIL INCLUDES CRUDE AND NATURAL GAS LIQUIDS

Figure 1.- Projected domestic oil production.

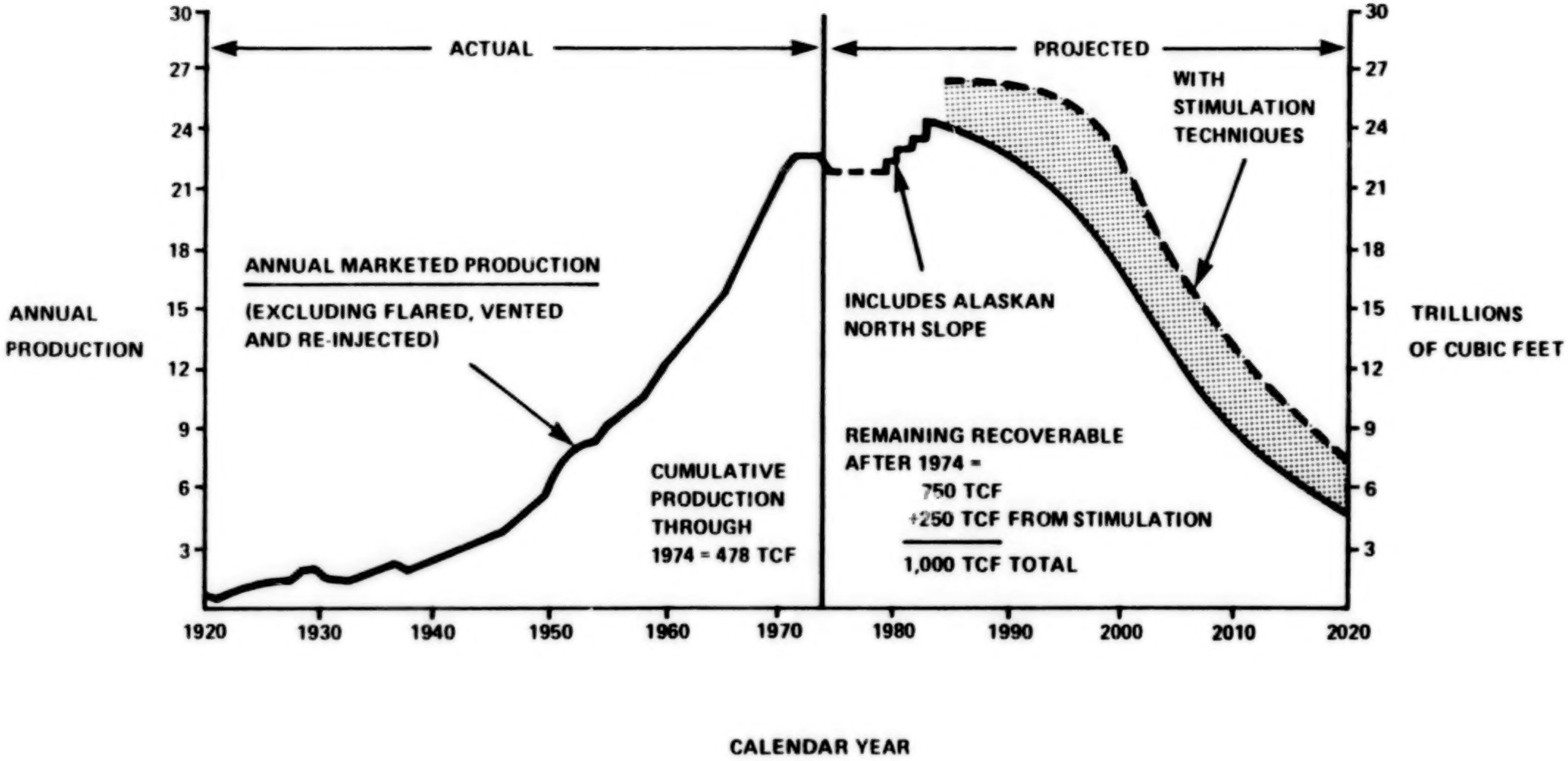


Figure 2.- Projected domestic natural gas production.

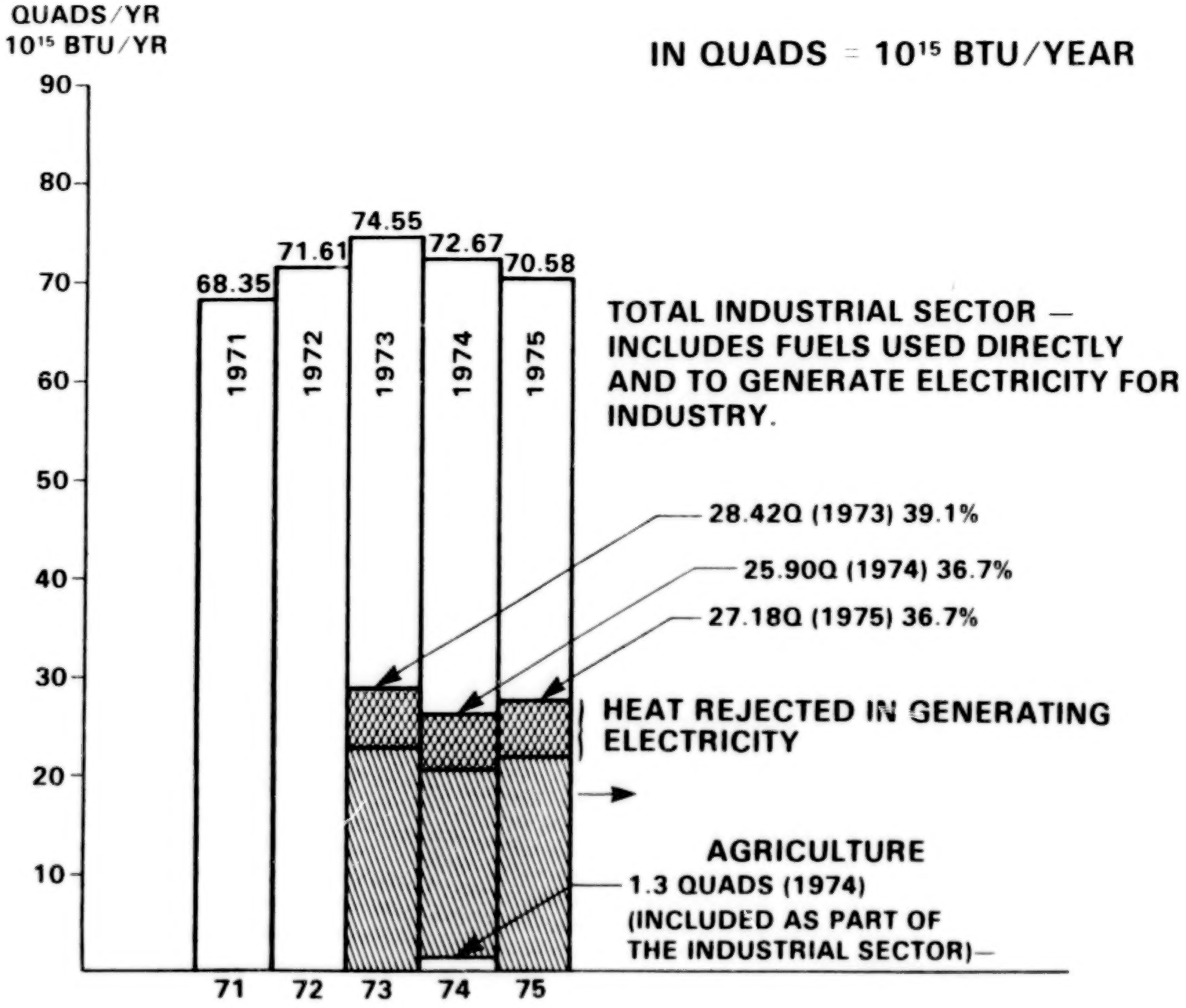


Figure 3.- Total U.S. energy consumption and industrial process heat.

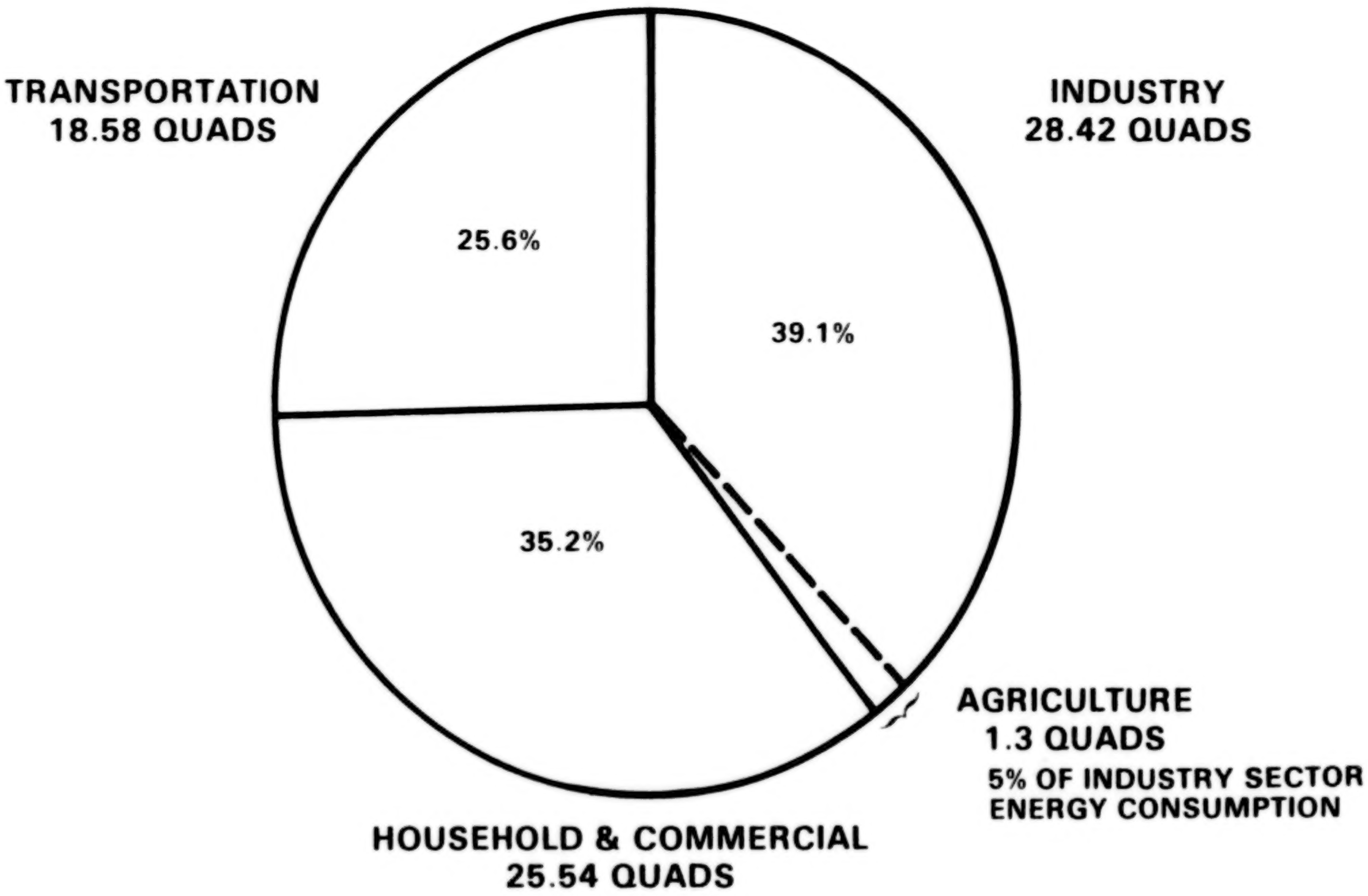
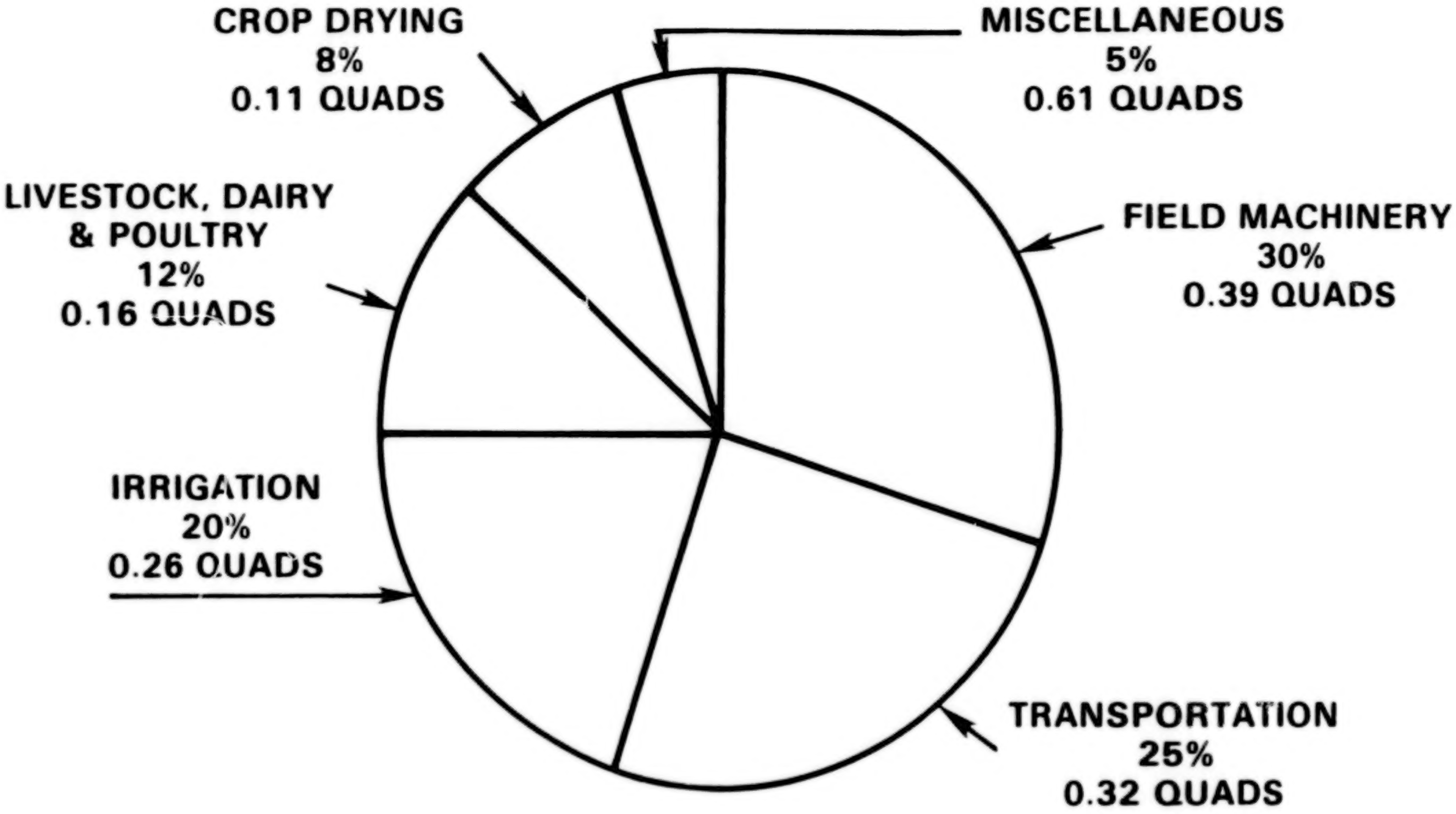


Figure 4.- United States 1974 energy consumption by major end use sector.

71.



1 QUAD = 10^{15} BTU

Figure 5.- Energy use in production agriculture - (1974) total fuels and electricity.

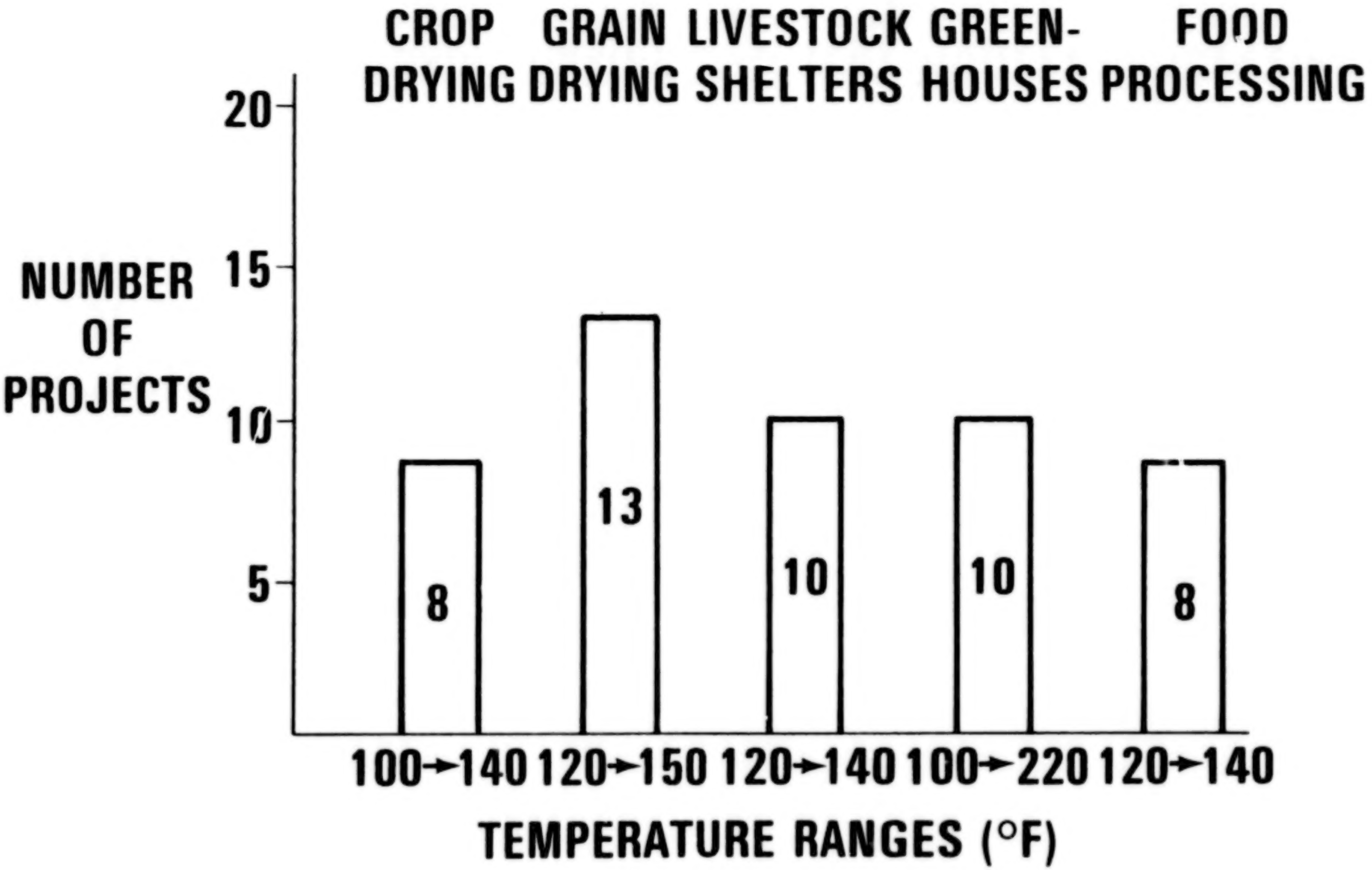


Figure 6.- Agricultural process heat projects.

73

74.

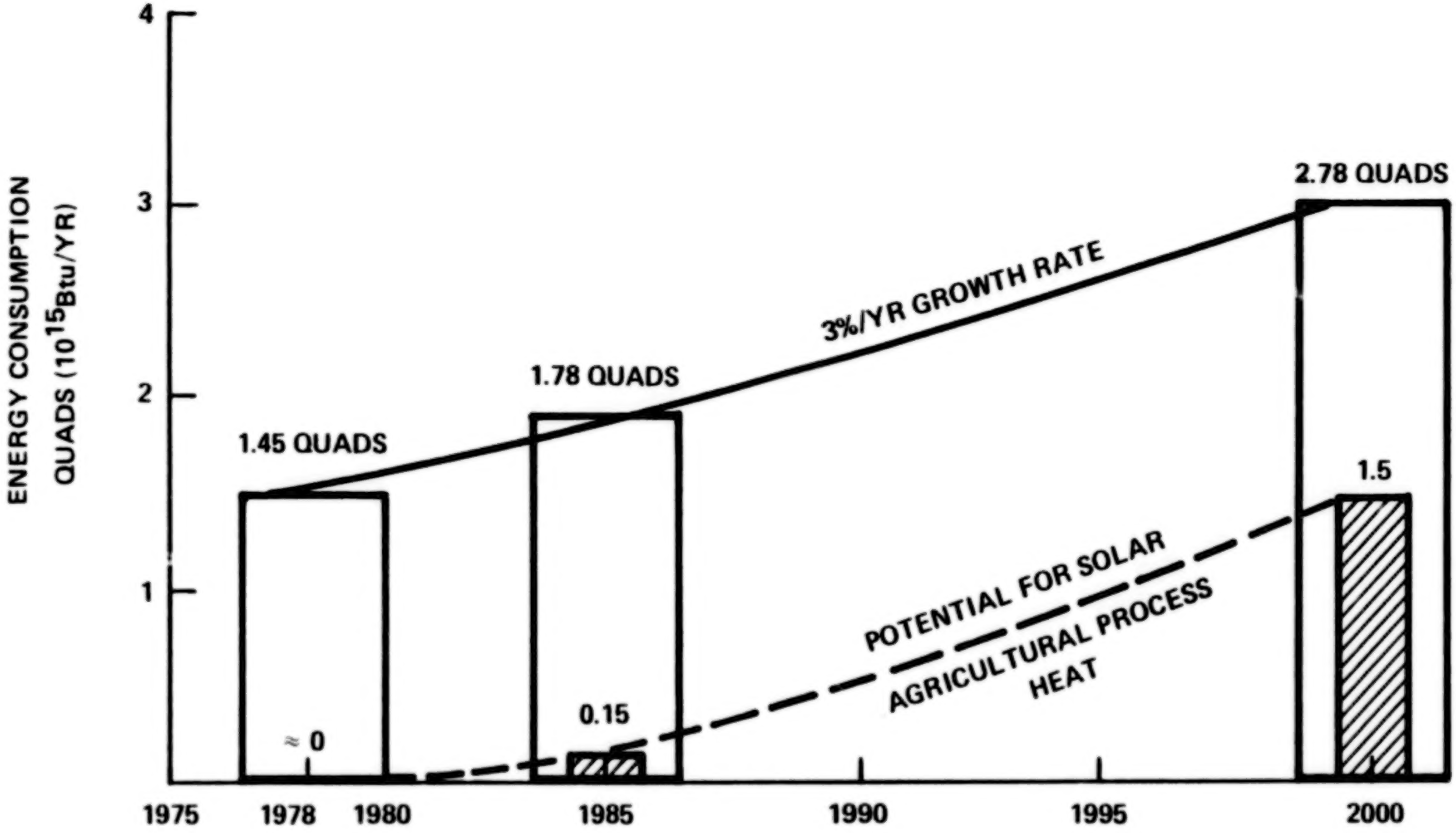


Figure 7.- Agricultural process heat projected demand and solar potential.

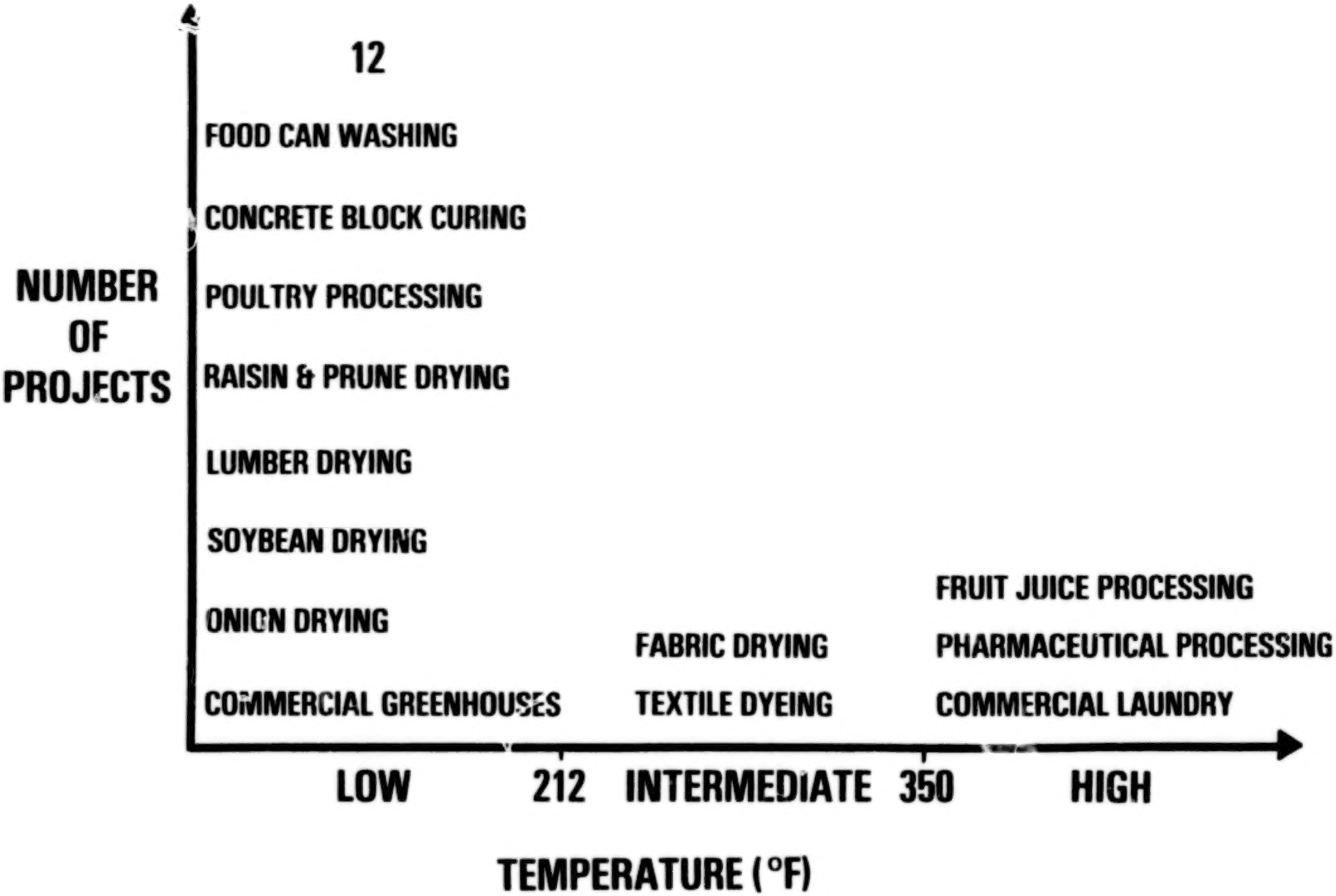


Figure 8.- Solar industrial process heat projects.

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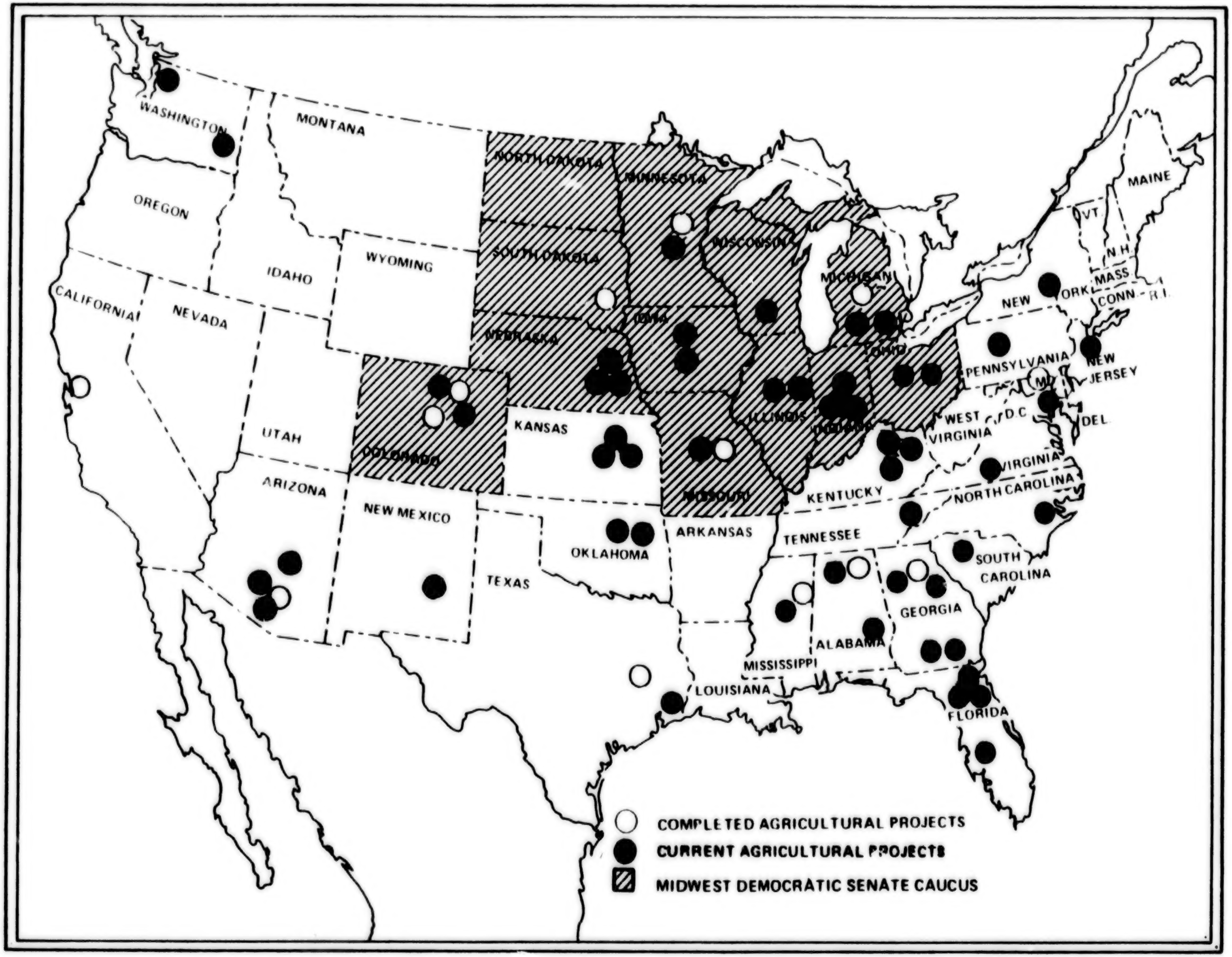
	FY 77			FY 78								
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
CROP DRYING			PROPOSALS DUE CYCLE 4 ▽							AWARD CYCLE 4 CONTRACT ▼		
GREENHOUSES				PROPOSALS DUE CYCLE 4 ▼						WORKSHOP ▽		AWARD CYCLE 4 CONTRACT ▼
LIVESTOCK SHELTERS							PROPOSALS DUE CYCLE 4 ▽					
GRAIN DRYING	AWARD CONTRACT CYCLE 4 ▽									PROPOSALS DUE CYCLE 5 ▽		
FOOD PROCESSING		AWARD CONTRACT CYCLE 2 ▽								PROPOSALS DUE CYCLE 3 ▼		

Figure 9.- Agricultural process heat milestones.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○ COMPLETED AGRICULTURAL PROJECTS
● CURRENT AGRICULTURAL PROJECTS
▨ MIDWEST DEMOCRATIC SENATE CAUCUS

Figure 10.- Location of agricultural solar projects.

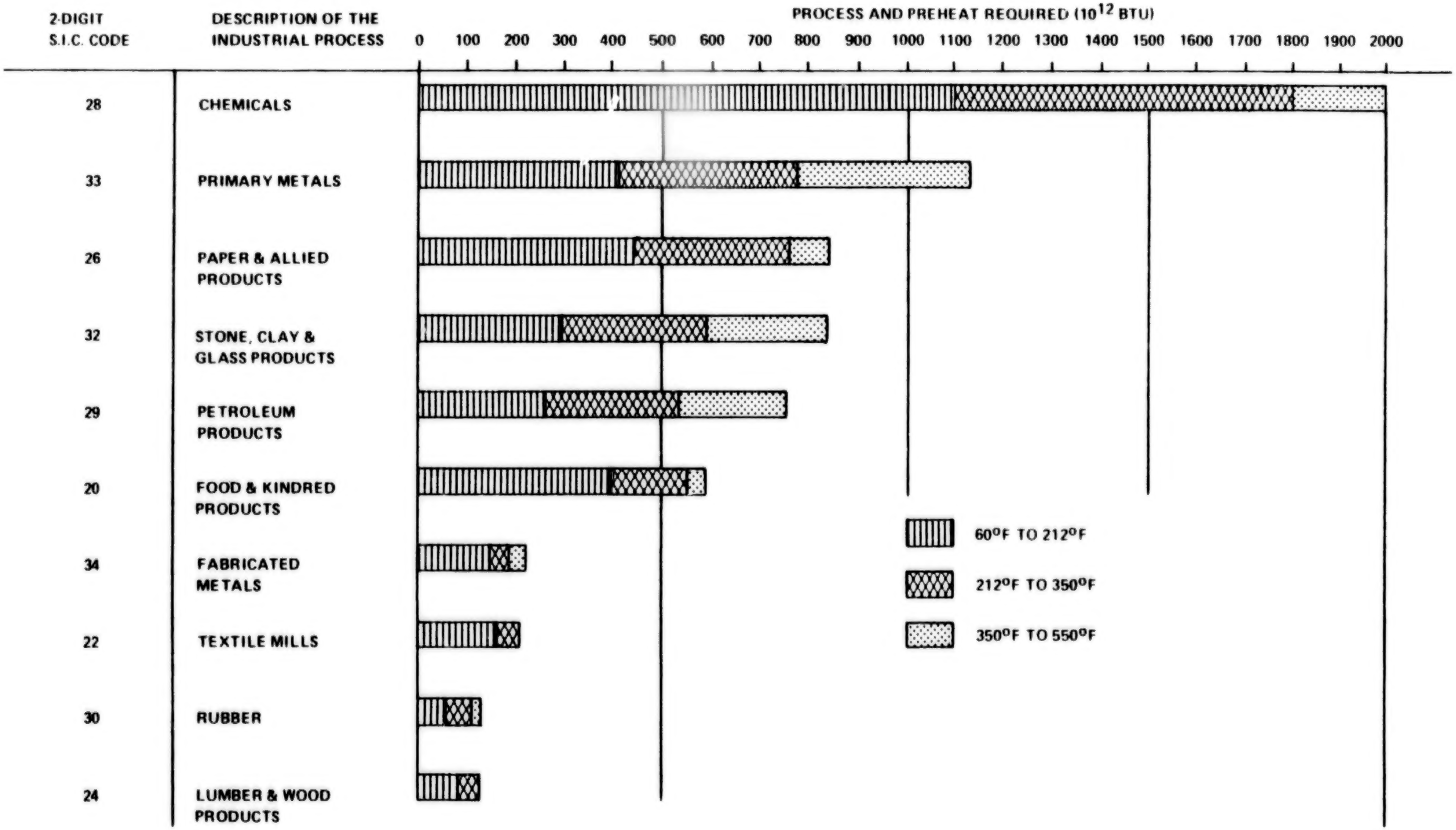


Figure 11.- 1976 process and preheat requirements (<550°F) in 10 selected manufacturing industries.

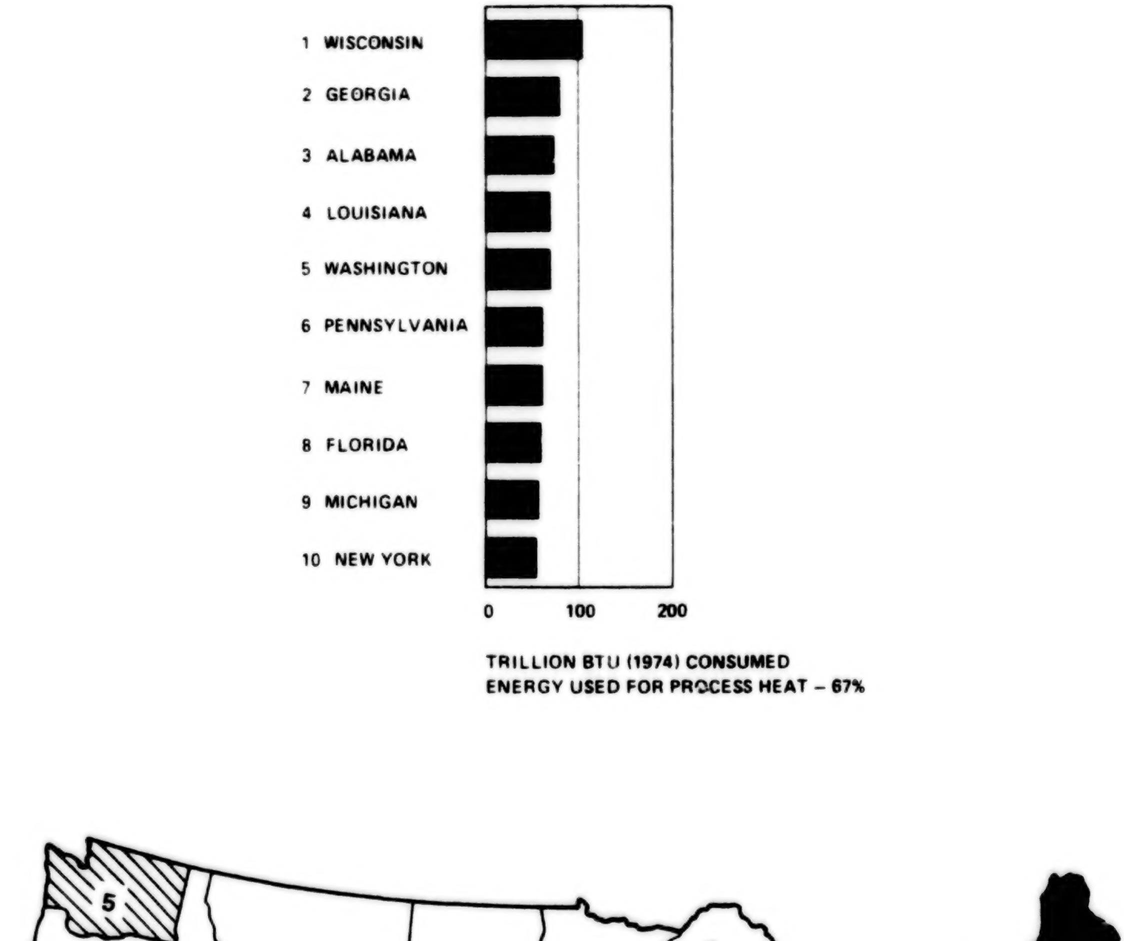
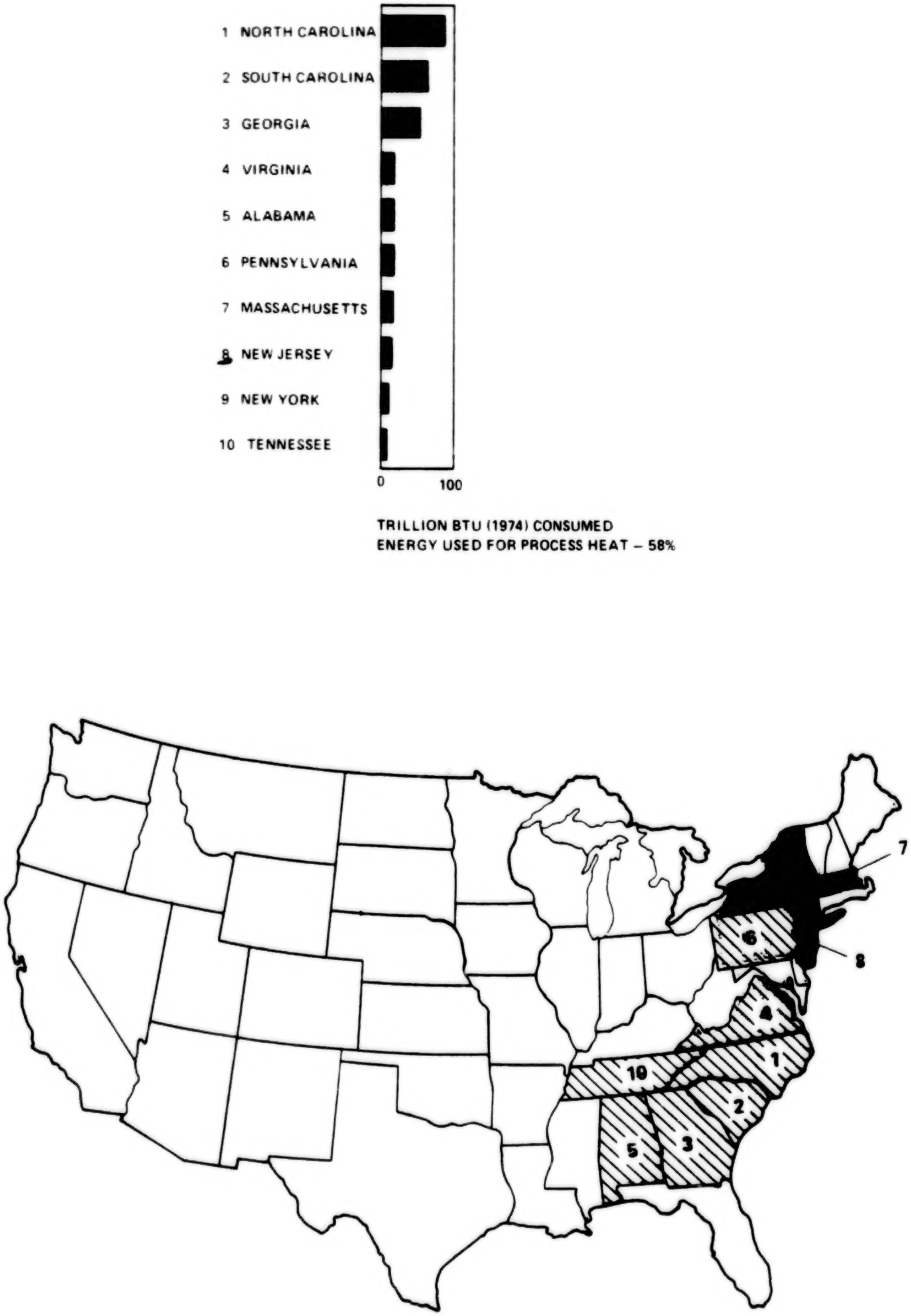


Figure 12.- Energy consumption paper and allied products.



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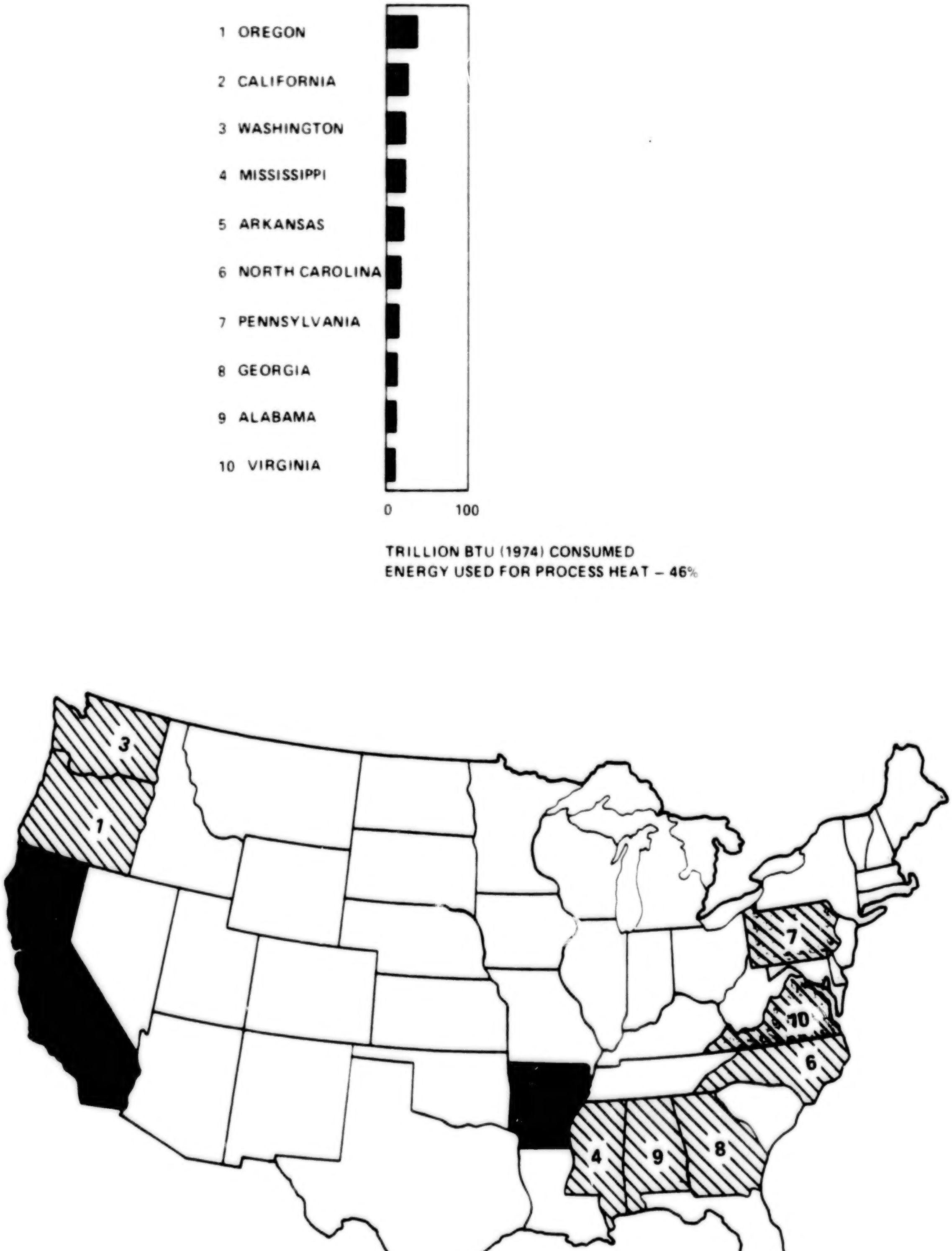

Figure 14.- Energy consumption lumber and wood products.

(Source: Patterns of Energy Consumption in the United States, Stanford Research Institute)

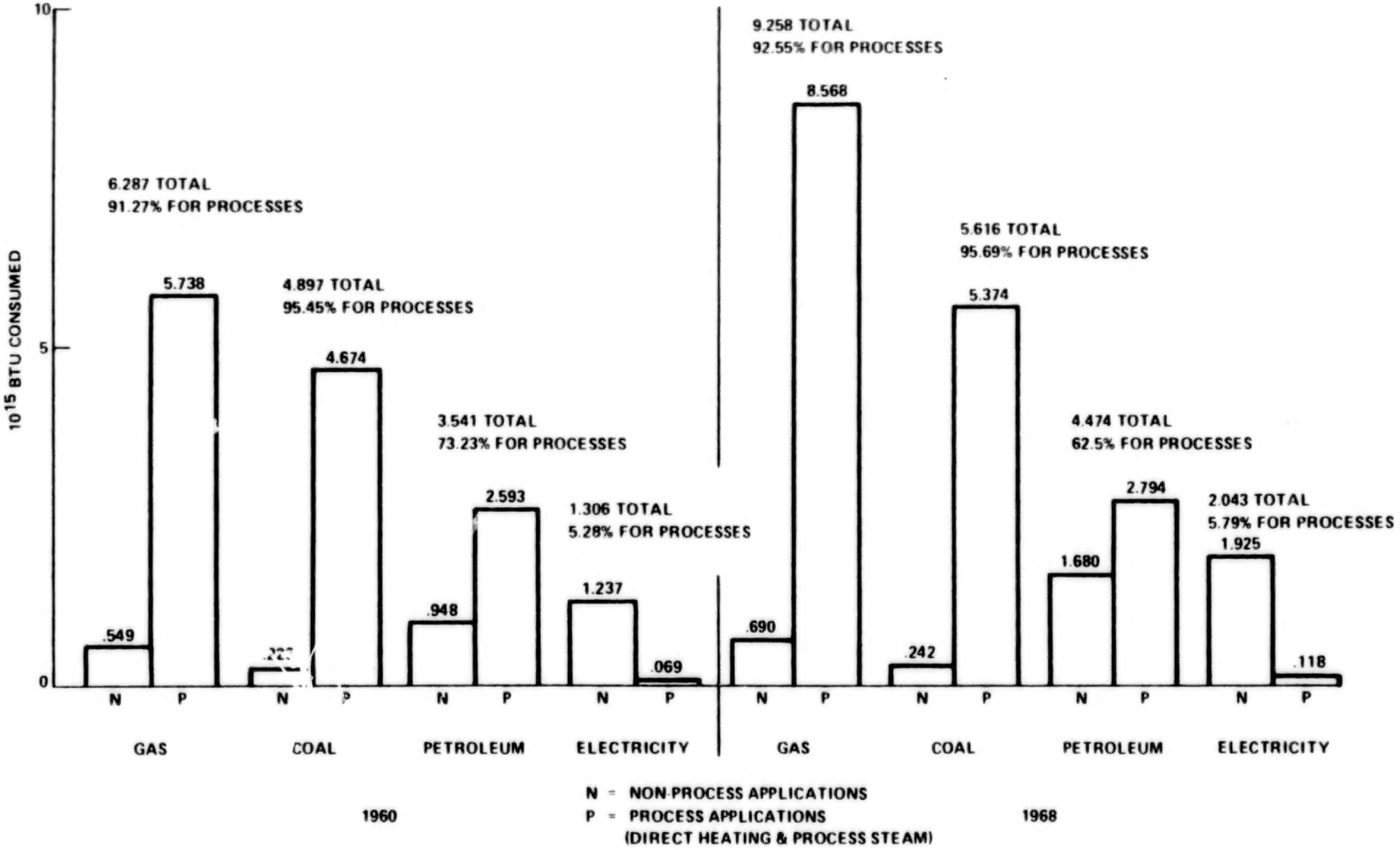

Figure 15.- Amounts of fuel types and electricity used for direct heating and process steam generation in 1960 and 1968.

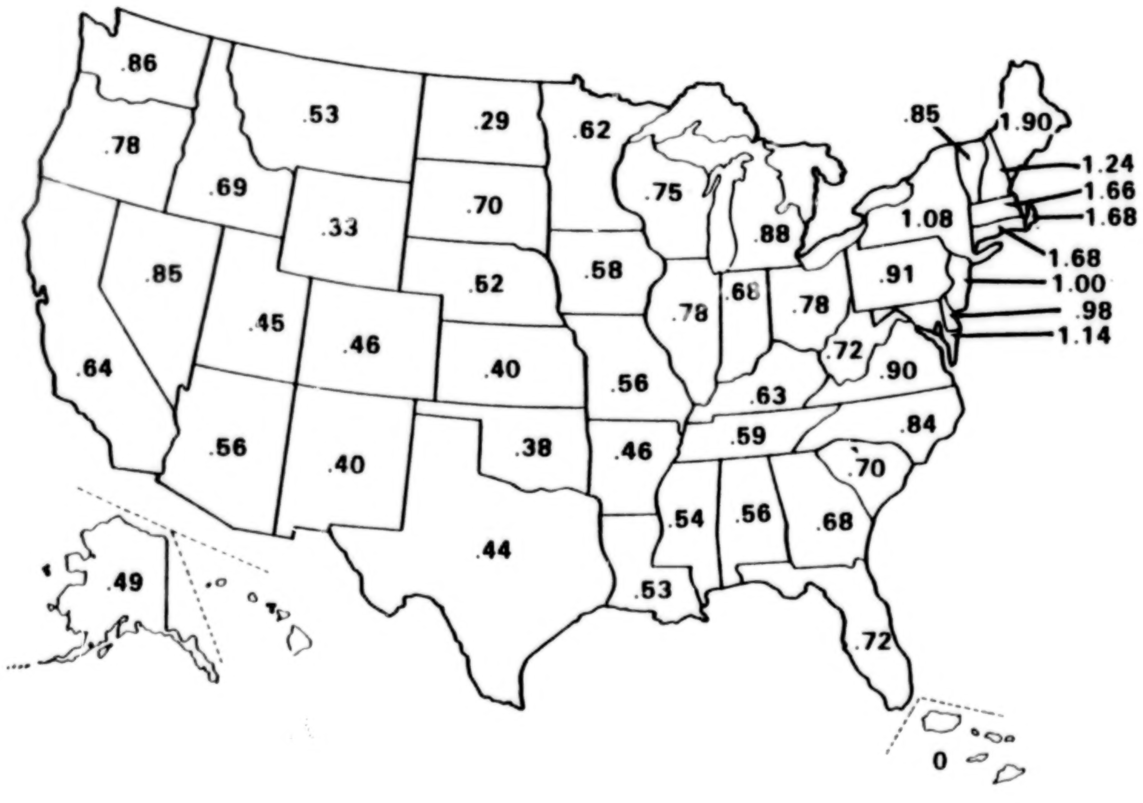
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Figure 16.- Industrial rates for natural gas (1974) ($ per 10^6 btu). (Source: Annual survey of manufacturers 1974 Bureau of the Census, Department of Commerce.)

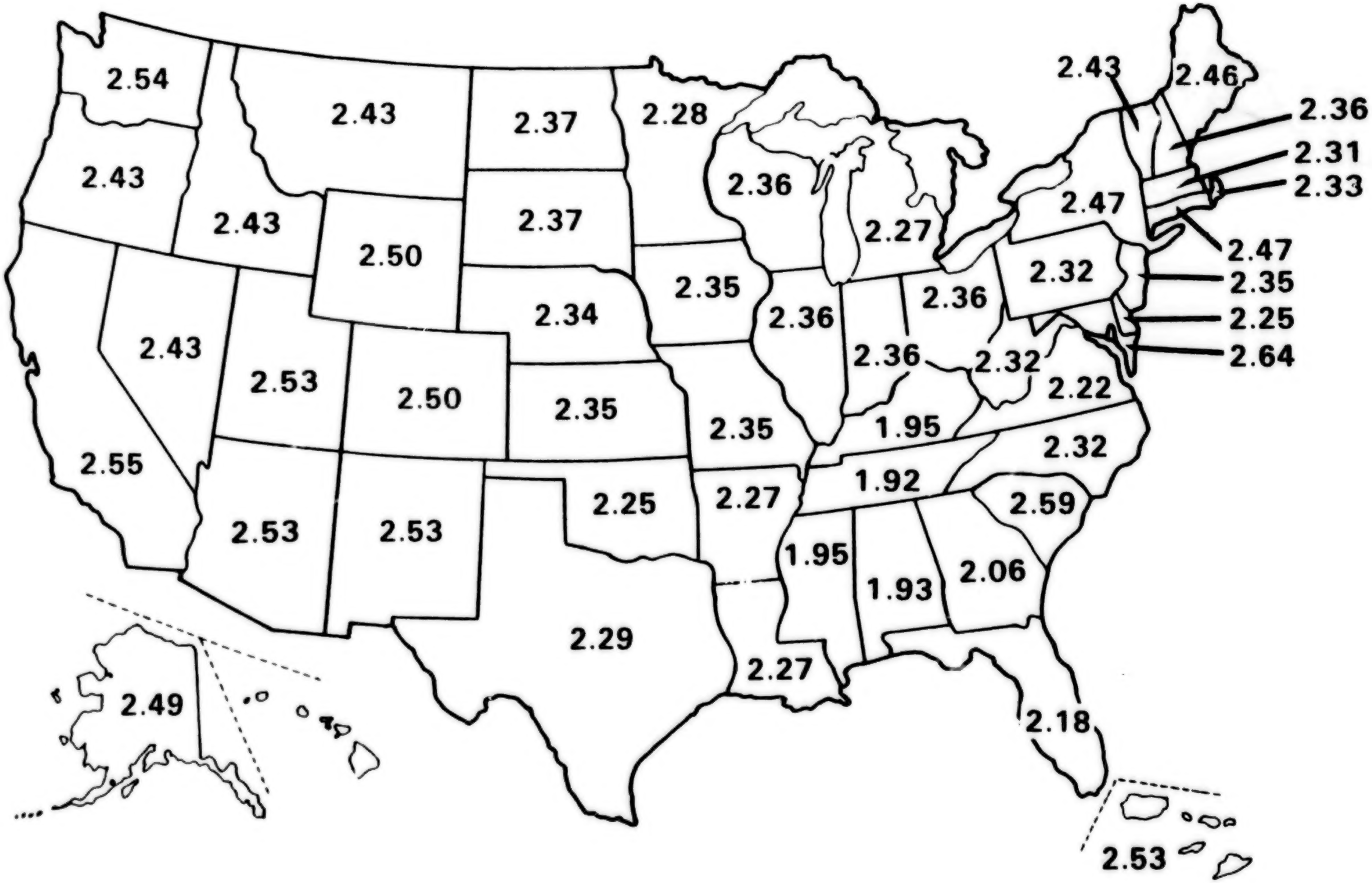
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Figure 17.- Industrial rates for distillate oil (1974) ($ per 10^6 btu). (Source: Annual survery of manufacturers 1974 Bureau of the Census, Department of Commerce.)

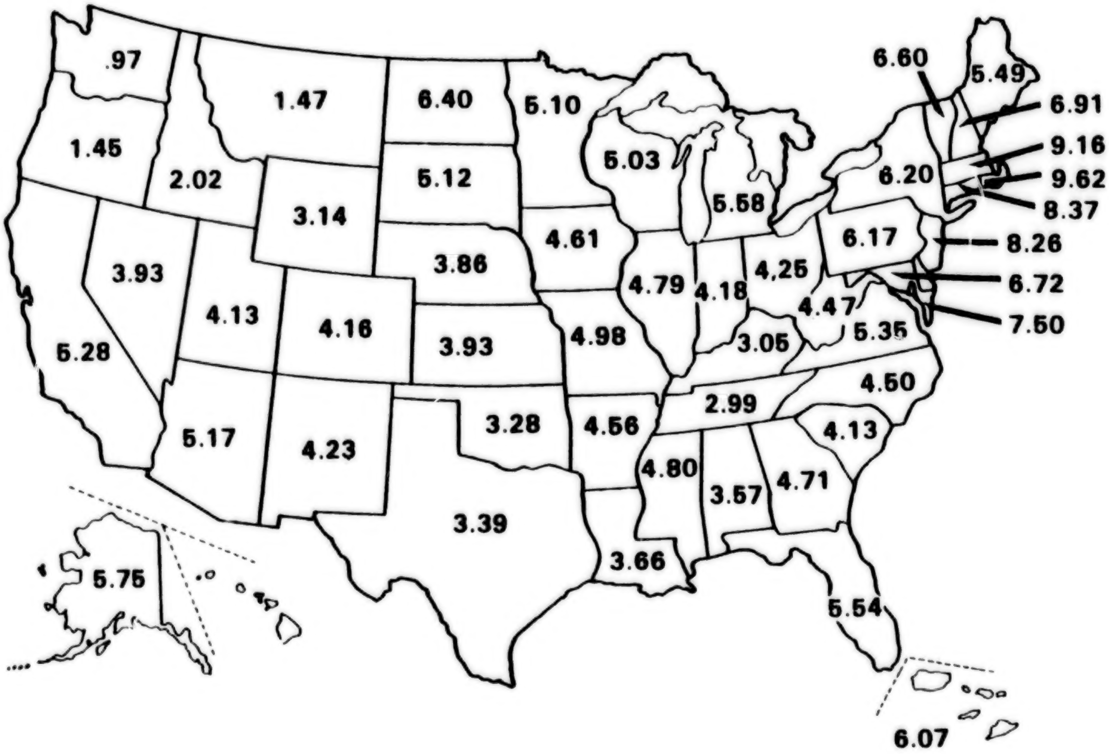
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Figure 18.- Industrial rates for electricity (1974) (\$ per 10^6 btu). (Source: Annual survey of manufacturers 1974 Bureau of the Census Department of Commerce.)

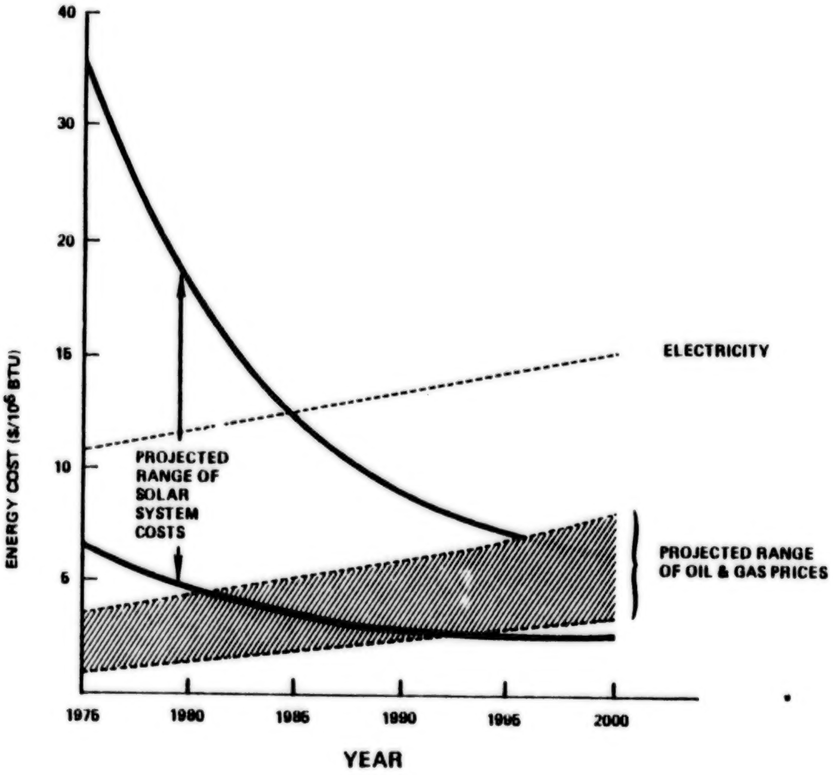

Figure 19.- Comparative solar and fossil fuel costs.

CONSERVATION AS AN ALTERNATIVE ENERGY SOURCE

DONALD E. ALLEN
DEPARTMENT OF ENERGY

INTRODUCTION

Thank you ladies and gentlemen, I appreciate this opportunity to meet with you today. The title of this symposium, "Emerging Energy Alternatives for the Southeastern States" sets the stage, of course, for the program and topics to be addressed by the speakers. The topic of my discussion, "Conservation as an Alternative Energy Source," can't really be addressed adequately without some recognition of our overall energy problem, which in turn, should lead us to a recognition of the need to conserve the energy resources we have available to us today. Further, although the primary thrust is upon the southeastern states, I find it very difficult, if not impossible, to focus upon a single geographic region without focusing on the Nation as a whole. Although actual conservation measures may vary slightly in their application from region to region, conservation principles and policies affect all of us, regardless of the region we live and work in.

The difficulties we are witnessing today underscore once again the fragility of the energy situation in which the U.S. finds itself. We are all dependent on what is a very fragile, logistical system for the most part, increasingly dependent upon the flow of petroleum from overseas sources of supply - and as the fire in Saudi Arabia indicated just last Spring, even under the best of circumstances, that system is susceptible of disruption.

That was a warning, as the just concluded coal strike was a warning, as the embargo in 1973-74 was a warning, as last year's natural gas crisis was a warning. I hope that we would not need too many more warnings before we begin to deal with the Nation's energy problems and dispel the wishful thinking that somehow or other the current episode is one that is not representative but instead is simply a random event.

Our system for energy production and use is delicately balanced and it creates dilemmas. If we become increasingly dependent on coal, as I believe we must, and as the thrust of the National Energy Plan suggests, we become more vulnerable to the kinds of work interruptions that we faced in the coal industry until last week. Yet running those kinds of risks of temporary interruption of supply from such work shortages is far less difficult a contingency to face that to be running short of energy because of international pressures, or simply a restriction on available supply.

The energy problem of the U.S. can be surmounted if we all act wisely in this country. It will require us to act with foresight and with vision. It will require us to take advantage of the lead times that we still have available before the Nation runs into the most intractable of its energy problems.

Those are long lead times, seven, eight, ten, twenty years, and it is one of the aspects that is frequently forgotten by those who would recommend some instantaneous magic solution to the energy problem that we face.

In order to bring about the change in the pattern of energy use in the U.S. over the next eight or ten years, we must take advantage of the lead time and recognize what those lead times involve. If we fail to take advantage of those lead times, sometime in the 1980s we will run into serious problems with regard to the availability of our energy supply. Under those circumstances, we in this country would be forced to act hastily simply because we are suddenly faced with an emergency that we had not anticipated, and as a result of being forced to act hastily, we would act ineffectively. We would have far greater government involvement in decisions that would have been better left to individuals and to corporations, and we would be acting belatedly, failing to take advantage of the time to make adjustments to our prospective difficulties.

Our energy problems are relatively simple. The principal fuel of choice for the U.S. and much of the rest of the world since World War II is becoming increasingly difficult to produce in ever-increasing quantities. It is not so much that we are running out of oil. Rather, the demand for oil is so voracious that we cannot continue to increase our productive capacity worldwide to satisfy that demand.

Sometimes it is wise to reflect on how our appetite for petroleum has grown even in this country. In the first seven days of July of last year, motorists in the U.S. used more gasoline than the ground forces of the U.S. used during the peak year of World War II. The first two weeks of July, motorists in the U.S. used more fuel than the Army Air Forces during the peak years of World War II. Our capacity to burn fuel has expanded enormously, almost ten-fold since World War II, but our capacity to produce has not grown concurrently.

At this point, I want to stress the drastic changes that lie before us in the availability of fuel, in the supply of oil on a worldwide basis.

Our appetites are indeed voracious. Each year now the world consumes over 20 billion barrels of oil, approximately 1% of the total amount of oil that the geologists in their wildest dreams ever expected might be out there to be discovered and recovered.

Given this worldwide consumption, in order to maintain our world reserves, we would have to discover a new north slope of Alaska every six months, or a new North Sea every year and a half, or a new Kuwait every three years, or indeed, even a new Saudi Arabia every seven or eight years. That is not going to happen. We cannot maintain our current rate of consumption. Gradually, on a worldwide basis, we are drawing down our reserves.

Do not be deceived by anything that you may read in the newspapers about worldwide gluts, excesses and so forth. There is a transportation problem on the Pacific Coast of the U.S., such that we are unable to deliver cheaply a local oil surplus to the eastern part of the U.S., which depends overwhelmingly on foreign sources of supply. Around the world today we probably have two to three percent excess production. This is no surprise. Even the famous CIA report of seven or eight months ago underscored the fact that when we brought on the north slope and the North Sea, for a year or two the world's demand for additional oil from the OPEC Nations would decrease. For the most part, however, we are operating very close to capacity levels. With a growth in demand for oil of almost five percent a year, it will not be long before we have reached the final limits of expansion in conventional production. We are probably about ten million barrels a day away from that on a worldwide basis, and sometime in the early or mid-1980s we will reach an effective ceiling. That does not mean that we will run out.

By the year 2000 we will probably still be fifty percent dependent upon oil and natural gas, substantially less than today.

The point I should underline is the importance of not attempting to evade what is a painful reality: that we are going to have to change, and that the easy access to energy resources we have increasingly enjoyed since World War II will gradually come to an end.

How do we deal with that problem?

I think the right line of approach is clear. We must take advantage of the time that is available to us, gradually to adjust our capital stock—our homes, our automobiles, our factories. Time is on our side if we take advantage of it, gradually to increase the efficiency of the automobiles in the fleet, increase the efficiency of space-heating in our homes, obtain conservation in all sectors of our economy. This can only be done by taking advantage of time. We must also move toward greater fuel efficiency and shift toward more abundant resources.

In 1943, Secretary of the Interior Harold D. Ickes, who was then the petroleum coordinator for the U.S., wrote a book called "Fighting Oil" in which he said: "Here may be as good a place as any to face squarely a set of realities.

We have long comforted ourselves with the belief that the U.S. has an unlimited supply of petroleum; that we would never be caught short. This is a misconception that cannot be used as a basis for any far-reaching conclusions. Our supply is not inexhaustible." That was 1943.

Ickes' words are well taken. They describe the problems that we face today, and with which we try to grapple with in the National Energy Plan; a plan that represents a very major step forward, a plan that was developed as a result of hard and extended consideration of the various issues that had to be addressed.

We must be flexible about the National Energy Plan. No one can anticipate the future; nobody can anticipate changes in circumstances, changes in technologies, so the plan must be adaptable to change in the future. We must be prepared for modification, and, I should point out that the National Energy Plan is designed as a minimum.

It will not eliminate dependence on foreign sources of supply. We will not achieve energy independence, as was advertised some years ago. We will continue to rely to a considerable extent for our oil on imports - but it will put us in a position in which we can survive the interruption of supply.

Modifications to the plan will be needed, since this is a minimum plan. I feel sure it will have to be strengthened this year, and later on, if we are effectively to make use of the time that is available to bring about that adjustment of our economy.

Now, the plan does things that are quite simple. It encourages conservation, and we have been wasteful. It encourages the shift to more abundant fuels—coal, uranium, new inexhaustible supplies such as solar power. It does so by encouraging us to move away from oil and gas which are the fuels that provide seventy-five percent of our energy today. This is indispensable - but it is painful. Why do we move away from oil and gas, particularly in its use in the factory? Well, there is no substitute for liquid fuels in our transportation sector. We have not yet designed an automobile that will run on solar power. Liquid fuels are essential for effective transportation. The penalty of shifting from oil and natural gas to coal in stationary facilities is relatively minor. So, if we are to have the resources, the fuel resources for our transportation sector, we must begin to make that adjustment where we can do so with relative convenience in our factories. That is the purpose of many of the economic measures in the plan.

I've mentioned that the plan is heavy on moving away from oil and gas, which is understandably a sensitive issue to several industries. The price mechanism is employed; it is reinforced by tax measures, but it is necessary to get the price signals right. Otherwise businesses are likely to invest now in gas or oil-fired facilities and when half of the life time of those facilities still remains, there will not be the fuel available - or, fuels will be available only at a very great cost. We must plan for the longer run. That is what we are attempting to do, and it is exceedingly difficult, because we do not have an immediate storage. We have a crisis, without a shortage.

Therefore, one must conceptualize the problem. Unless we are successful, as a democratic country, in dealing with the problem, we will have very heavy weather in the 1980s.

Now, even though President Carter's energy bill is still stalled in Congress, there are many parts of the National Energy Plan which both Houses of Congress and the Conference Committees have generally agreed to, including the conservation measures. I think you can get the gist of what the measure attempts to do in the conservation area.

These include

(a) A Utility Conservation Program for residential buildings.

(b) Weatherization Grants for multi-family housing and for the benefit of low-income families are included.

(c) There is secondary financing for energy conserving improvements and solar energy systems, and

(d) Energy conservation standards are to be developed for new residential buildings assisted by the FHA and insured by the FHA.

(e) There is a very large grant program ($900 million) for the retrofitting of schools, health care facilities, and public buildings.

(f) Appliance efficiency standards for thirteen categories of home products and appliances will be established.

(g) Automobile fuel efficiency standards will be required - and a gas-guzzler tax will be applied where minimum mileage standards are not met.

(h) Federal funding of the presently in-place state energy conservation plans is continued for two more years.

(i) There is an Industrial Energy Conservation Program.

(j) Also, a program to demonstrate solar heating and cooling in Federal buildings - as well as a separate program for implementing energy conservation and solar energy measures in Federal buildings.

- and on and on. There are many more parts of the conservation portion of the National Energy Plan.

As you can see, conservation plays a very important role in the National Energy Plan. Let us look more closely at conservation. Conservation is the cleanest and cheapest source of new energy supply.

It is an alternative energy source. Wasted energy—in cars, homes, commercial buildings and factories—is greater than the total amount of our oil imports. By reducing the need for additional oil imports, conservation and improved efficiency in the use of energy can contribute to national security and international stability. By reducing the need for additional domestic energy production, conservation can contribute to environmental protection and to an adequate supply of capital for balanced economic growth.

America needs to embrace the conservation ethic. The attitudes and habits developed during the era of abundant, cheap energy are no longer appropriate in an era of declining supplies of America's predominant energy sources. Conservation offers vast opportunities for American creativity and know-how. The challenge of saving energy should galvanize the ingenuity and talents of the American people. As individual Americans find new ways to save energy in their daily lives, they will reduce their own energy bills and contribute to the future well-being of the country.

In buying durable goods, in deciding how to travel to work or how to spend leisure time, and in making countless other decisions, Americans will have to be conscious of the rising price of energy, and will have to emulate the shrewdness and practicality of earlier generations.

For example, when buying a home, a car, or an appliance, consumers ought to consider not only an item's initial cost, but also its annual operating cost - including its energy consumption. In many cases, an item that is initially more expensive will actually prove to be cheaper over a period of years.

If vigorous conservation measures are not undertaken and present trends continue, energy demand is projected to increase by more than thirty percent between now and 1985. Americans can eliminate energy waste through effective conservation and improved energy efficiency in transportation, buildings, and industry.

Conservation is cheaper than production of new supplies. It can contribute to international stability by moderating the growing pressure on world oil resources. Conservation and improved efficiency can lead to quick results. For example, a significant percentage of poorly insulated homes in the U.S. could be brought up to strict fuel-efficiency standards in less time than it now takes to design, build, and license one nuclear powerplant.

Although conservation measures are inexpensive and clean compared with energy production and use, they do sometimes involve sacrifice and are not always easy to implement. If automobiles are to be made lighter and less powerful, the American people must accept sacrifices in comfort and horsepower. If industry is required to make energy-saving investments and to pay taxes for the use of scarce resources, there will be some increases in the cost of consumer products. These sacrifices, however, need not result in major changes in the American way of life or in reduced standards of living. Automobile fuel efficiency can be greatly improved through better design and use of materials, as well as by producing lighter and less powerful cars, without inhibiting Americans' ability to travel. With improved energy efficiency, the impact of rising energy prices can be significantly moderated.

Energy conservation, properly implemented, is fully compatible with economic growth, the development of new industries, and the creation of new jobs for American workers. Energy consumption need not be reduced in absolute terms; what is necessary is a slowing down in its rate of growth. By making adjustments in energy consumption now, the U.S. can avoid a possibly severe economic recession in the mid 1980s.

The U.S. has a clear choice. If a conservation program begins now, it can be carried out in a rational and orderly manner over a period of years. It can be moderate in scope, and can apply primarily to capital goods, such as homes and automobiles. If, however, conservation is delayed until world oil production approaches its capacity limitation, it will have to be carried out hastily under emergency conditions.

With the diminishing supply of fossil fuels, coupled with the continuing rise of fuel prices, the incentive for energy conservation, really, should be very apparent to all of us.

There is a tremendous potential for energy conservation in the residential and commercial sectors of the ecomomy, as well as in the industrial sector, with potential annual savings of millions of barrels of crude oil equivalents. Through programs such as this one you are attending here today, it seems to me we can make very positive strides in achieving this objective, and assuring the continued economic well being of our country.

1978 is the year of the horse, my Asian friend reminds me. The next year of the horse in the oriental zodiac will be 1990. Unless we get cracking to conserve and develop alternative fuels before then, 1990 could be the year of the horse, "and buggy," for the western, industrialized world.

Reverting to the horse would be returning to a renewable energy source, I suppose, but it would also be closing the circle counterclockwise. We simply cannot tolerate being the first generation of Americans to move backwards in history.

My best efforts, and your best efforts, to help save us from that fate will be welcomed.

Thank you very much.

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THE IMPACT OF MUNICIPAL REFUSE UTILIZATION ON ENERGY AND OUR ENVIRONMENT

H. L. GREENE
Langley Research Center

SUMMARY

Utilization of refuse as a source of energy is a relatively new concept in the United States. Although practiced in Europe for 20 years, the Europeans are still on a learning curve, and we, of course, are just beginning. Industry, here and abroad, is continuously coming forth with new ideas and concepts but to date none have proven as reliable as the "conventional" incinerator/boiler configuration. Even this configuration is not without its problems. However, the high cost of refuse disposal and the ever increasing cost of energy have made the idea an attractive and even economically sound solution to two major problems.

DISCUSSION

It has been conservatively estimated that each person in this country generates about three pounds of garbage each day (fig. 1). With a population of about 220 million, this translates into 300 000 000 kilograms (330 000 tons) per day of refuse, refuse which must be disposed of in an environmentally acceptable manner.

The dangers to which our environment is exposed by the traditional method used to dispose of this enormous amount of refuse are entering more and more into the awareness of the public, and solid waste management is a challenge facing most municipalities (fig. 2). Traditional methods of disposal pollute the environment and waste valuable recoverable resources.

Actually, it is very difficult to accurately determine the total effect of landfill operations on the environment, and those effects will certainly differ between localities (fig. 3). For example, a hillside operation in Western North Carolina most likely does not have the potential for ground water contamination that a similar operation would have in low lying Coastal region where the water table is often at ground elevation (fig. 3).

With the cost of everything increasing, waste disposal is no exception and the probability of more rigid EPA requirements must be considered. Fuel is almost in a class by itself for percentage increase. Fortunately, these two problems together spell "opportunity". Of course, the possibility of turning a liability into an asset is always attractive.

There are several systems available today for converting solid waste to energy and others will be forthcoming in the next few years. Of those presently available, few have a proven track record of successful operation and probably none are operating as successfully as the owners initially had hoped that they would. However, there are successful plants, plants that are providing a means for disposal of refuse, while reducing the fossil fuel demand.

The better known processes for recovering energy from refuse are

(1) Pyrolysis (fig. 4) - There are several variations in the available pyrolysis systems. These variations will not be discussed here in detail. The important point is that there is very little operating history in the pyrolysis field. Demonstration plants have operated with varying degrees of success. The largest of these plants is the 1000 tons per day plant in Baltimore. Many problems have been encountered during startup and the plant is operating at a considerably reduced capacity. Other companies have also operated pilot or demonstration plants but they have not demonstrated experience with full-scale municipal plants.

(2) Co-Combustion of Refuse-Derived Fuels (RDF) (fig. 5) - Co-combustion of RDF is proving to be reasonably cost-effective where fossil-fuel-burning utility boilers are existing and the fuel can be supplemented with RDF. A 650 tons per day demonstration unit is in operation in St. Louis that utilizes two coal-fired boilers. The capital investment is relatively low since existing boilers can be utilized. However, some modifications to the boilers are required.

(3) Mass-Fired Steam Generating Systems Utilizing Waterwall Boilers (figs. 6 and 7) - Compared with the previously discussed processes, mass fired steam generating systems utilizing waterwall boilers have the longest operating history. There are several in this country with utility factors ranging from 60% to 80%. The first of its kind (in the U.S.) was built at the U.S. Navy Base at Norfolk. Virginia, and became operational in 1967. There are a half dozen others in the Eastern United States and Canada and literally scores in Europe and the Far East. Plants in Europe date back to 1957.

Although incineration, by whatever means, eliminates or reduces the potential pollution brought about by landfill operations, the energy reclaiming processes themselves may contribute to air and water pollution if not properly designed and operated. However, current technology is available that, when properly applied, will maintain polluting effluents at acceptable levels.

The public official who is responsible for selection of a refuse-to-energy system has the three choices discussed previously but the selection must not be made in haste. Any community considering the construction of a refuse-to-energy system should employ a competent engineering firm to perform a technical and economic analysis of the given set of circumstances (fig. 8). First and foremost, he must identify the energy customer. Secondly, he must determine the type of system that will produce the most (and best suitable form of) energy, and finally he must do a detailed economic analysis of the proposed system. This process is not as simple as it may sound (fig. 9). For example, assume that you find a steam customer who requires 500 billion Btu's per year in the form of steam, and you have fuel (refuse) available to meet the demand. It appears to be a good deal on the surface but will the energy demand be constant the year around? Probably not, and unfortunately, it is a fact of life that people generate more garbage (fuel) in summer months than they do in the winter. Then, too, the characteristics of refuse change from week to week and season to season. The constancy of energy output may be a problem.

Another point, is there a plant site available that will minimize energy transmission costs and meet the aesthetic requirements of the surrounding area?

Further, boilers, all boilers, have to be shut down for annual inspections and maintenance. Remember also that burning refuse is not like burning fossil fuels. There will be those unscheduled shutdowns. The question is then, what percent plant utility will you achieve? Can you afford the necessary redundancy (like a fossil fuel back-up boiler) to furnish the guarantees required by the energy customer? Because of these questions, the answers to which will probably differ at every location, we say that refuse-to-energy plants are "site specific". Each one must be tailored to a specific set of circumstances.

Now, I would like to discuss the facility with which I am most familiar and to describe briefly its impact on energy and our environment. Langley Research Center (LaRC) first began its investigations of refuse burning in 1971. However, at the time we were paying about 8¢/gallon for No. 6 fuel oil and the project was not economically viable. This situation changed drastically in 1973/1974 when energy costs began in increase by leaps and bounds (fig. 10). Accordingly, we began discussions with the personnel of Langley Air Force Base and the City of Hampton. Our concerns resulted in a study, completed in February 1974, by the Architect-Engineering firm of Day and Zimmermann.

The study showed that the proposed refuse-to-energy plant was both economically and technically feasible. An earlier report prepared by the Smithsonian Institute indicated that the Langley Air Force Base landfill should be closed (fig. 11). The City of Hampton was then involved in a search for a future landfill site, since the existing landfill life was estimated to be only 10 to 15 years. Most important of all, LaRC has a year around demand for energy. As a result of these findings, the Langley Research Center, the City of Hampton, and Langley Air Force Base have entered into a partnership to build a plant that will burn refuse and generate steam (fig. 12). The plant will be called the Refuse-Fired Steam Generating Facility (RFSGF). It will include two waterwall boilers and the required support equipment. Each boiler will burn about 91 000 kilograms (100 tons) of refuse per day, will operate 24 hours per day, and will generate 12 500 kilograms (27 500 pounds) of steam each hour at 2 413 000 newton/meter^2 (350 psig) and 225° C (436° F). Since the City has an average of 159 000 kilograms (175 tons) per day of refuse and the total Government refuse averages

23 000 kilograms (25 tons) each day, most of the available refuse will be burned. Langley Research Center is the sole energy customer. However, each year the boilers must be shut down for about six weeks for repairs and recertification. During that time, refuse will be taken to the City landfill and the LaRC oil-fired steam plant will supplement the RFSGF steam output as required.

The plant will operate as follows (fig. 13):

Trucks will dump refuse in the large concrete pit at the front of the building. The bridge crane will pick up the refuse and dump it into the charging hoppers. The refuse is dried and then burned on the 3-tier grate and the ash (residue) is dropped out at the opposite end onto residue conveyors. As the refuse burns, the hot 982°C (1800° F) flue gas rises and passes through the convection section of the boiler where steam is generated. Steam will be piped into Langley's existing steam distribution system and used throughout the Research Center. The hot gases pass on through the boiler and through an electrostatic precipitator where particulates - visible smoke - are removed. Stack emissions will meet or be better than the requirements established by the Environmental Protection Agnecy and the Virginia State Pollution Control Board. Residue is loaded on trucks and taken to the City landfill. Since the residue has been through the furnace, and essentially "sterilized", neither rats nor seagulls like it, it will be landfilled. This action will cause some increase in the total dissolved solids, hardness, and alkalinity of any body of water which receives leachate - ground water - from the City landfill.

The City will operate the plant on a 20-year lease. Plant revenues will be derived from garbage disposal fees (tipping fees) and steam charges. We estimate that operation of the plant will bring about a reduction in operating costs to both the Government and City systems.

The effect of the plant on our environment and our energy consumption is significant (fig. 14). As for the effect on our environment, reducing the amount of garbage being buried in the ground by about 70% reduces the potential of ground water pollution by a similar amount. Sulfur is, of course, one of the biggest pollutants from our existing plant. The fuel oil burned by Langley Research Center contains about 2.5% sulfur by weight where refuse has about one-tenth of one percent. In our case, burning refuse instead of oil reduces the amount of sulfur oxides in the air by about 62%. Since the new plant will be equipped with precipitators, particulate emissions will be reduced by about 5% from the present emission rate. Nitrogen oxides will be reduced by about 8%. There are increases in the outputs of carbon monoxide and hydrocarbons, but these emissions do not exceed allowable levels.

As for the energy problem, the plant will save about 9.5 million liters (2.5 million gallons) of fuel oil each year or enough to heat 2 500 homes. This is a small amount of oil when compared with the total energy used in the country each year, but it is a step in the right direction.

To see what the big step would be, let us assume for a moment that all refuse generated in this country could be efficiently utilized as a fuel - 109 billion kilograms (120 000 000 tons) per year containing about 7.60×10^{17}

joules (7.2 10^{14} Btu) which, at todays cost of No. 6 fuel oil (33¢/gallon), translates into about $2.0 billion. (Since we are importing about 40% of our annual oil demand, this is a savings in the trade deficit.)

In conclusion, it is my opinion, after four year of study and analysis, that every community faced with refuse disposal problems should investigate the feasibility of refuse-to-energy facilities in their area (fig. 15). Discussions between community leaders and local industry (or local Federal Agencies) won't cost the taxpayer a cent and they may turn up a set of circumstances where each can help the other. The LaRC/City of Hampton Cooperative Agreement is unique in some respects. It does show that organizations, for example, government jurisdictions, can work together to the benefit of the taxpayer (fig. 16). This cooperation must take place if we are to solve these two pressing problems. In our case, the RFSGF impact of municipal refuse utilization will be positive in that it saves fossil fuel and **decreases environmental pollutants.**

Figure 1.- Municipal refuse - a national problem.

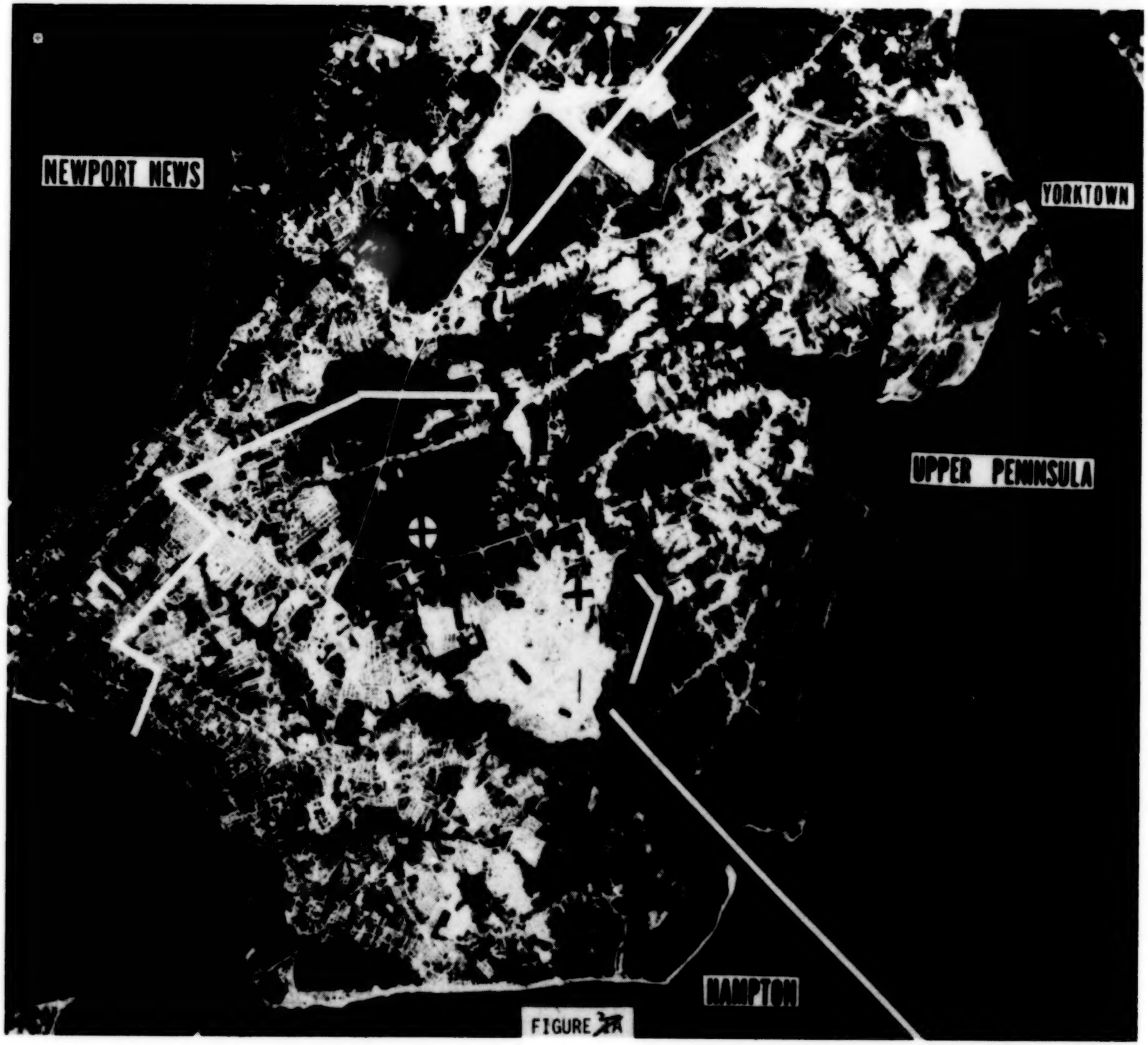
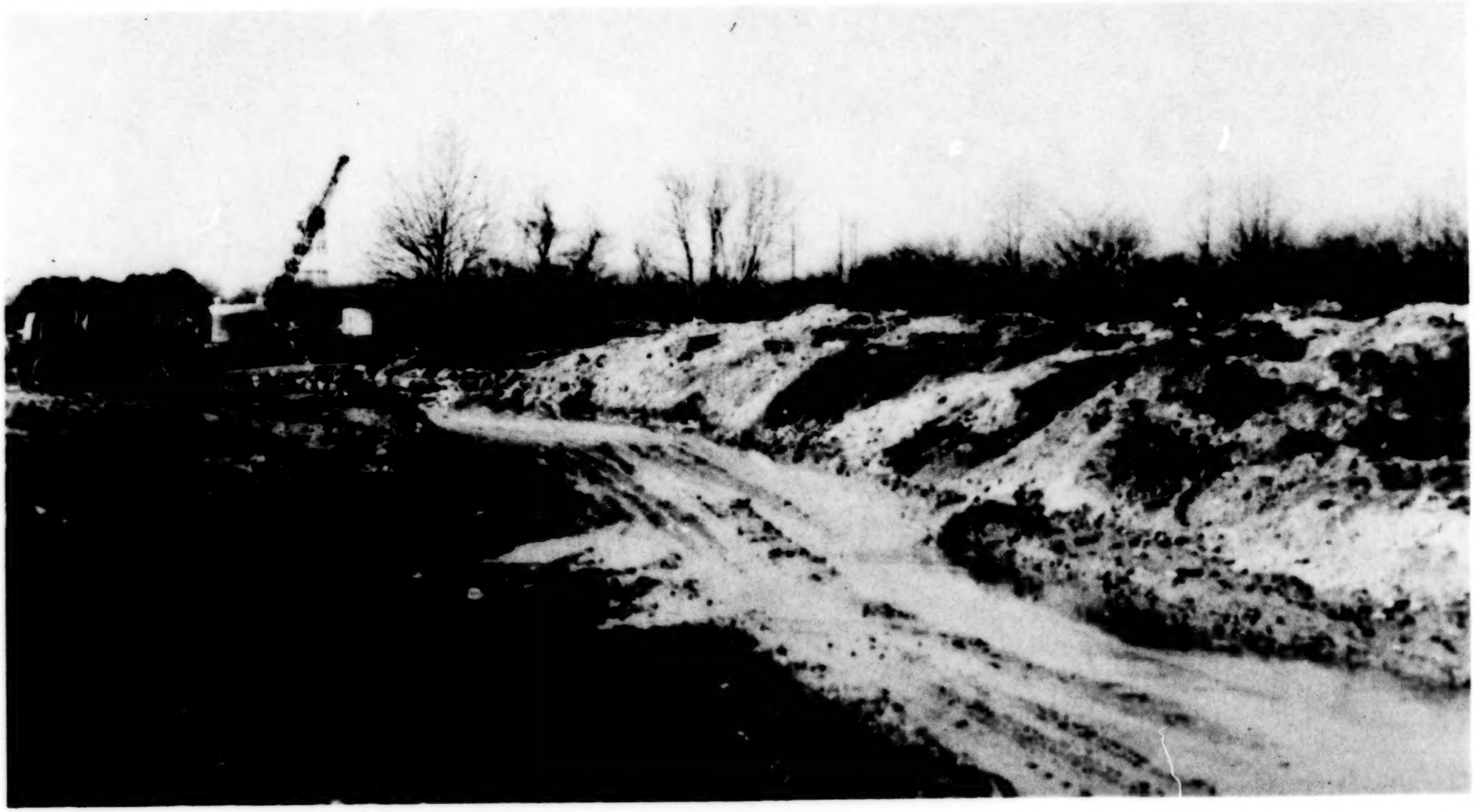
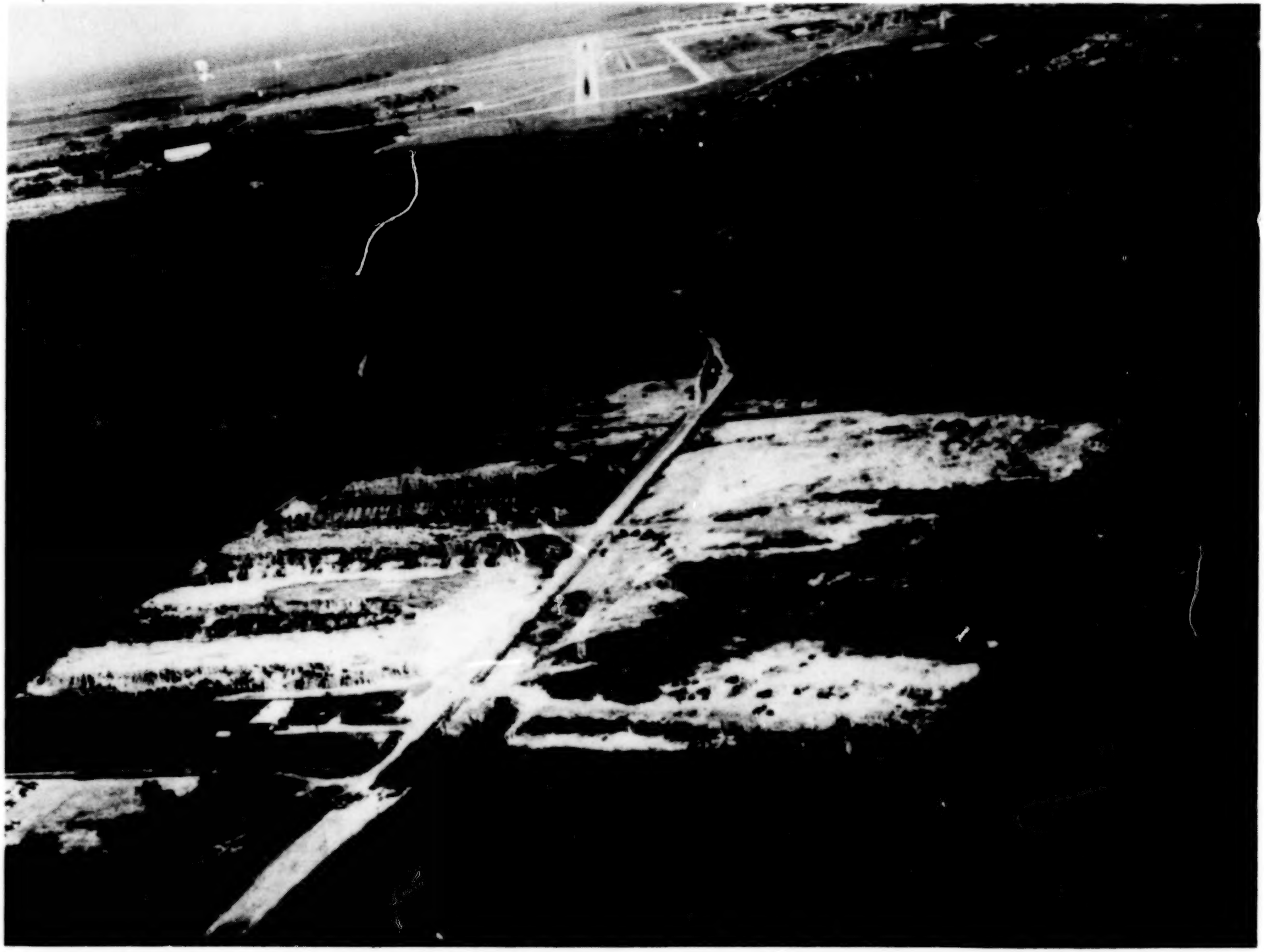

NEWPORT NEWS
YORKTOWN
UPPER PENINSULA
HAMPTON
FIGURE 3A

Figure 2.- Municipal refuse - our local problem.



(a) Langley Air Force Base landfill.

Figure 3.- Typical landfills.



(b) City of Hampton landfill.

Figure 3.- Concluded.

103.

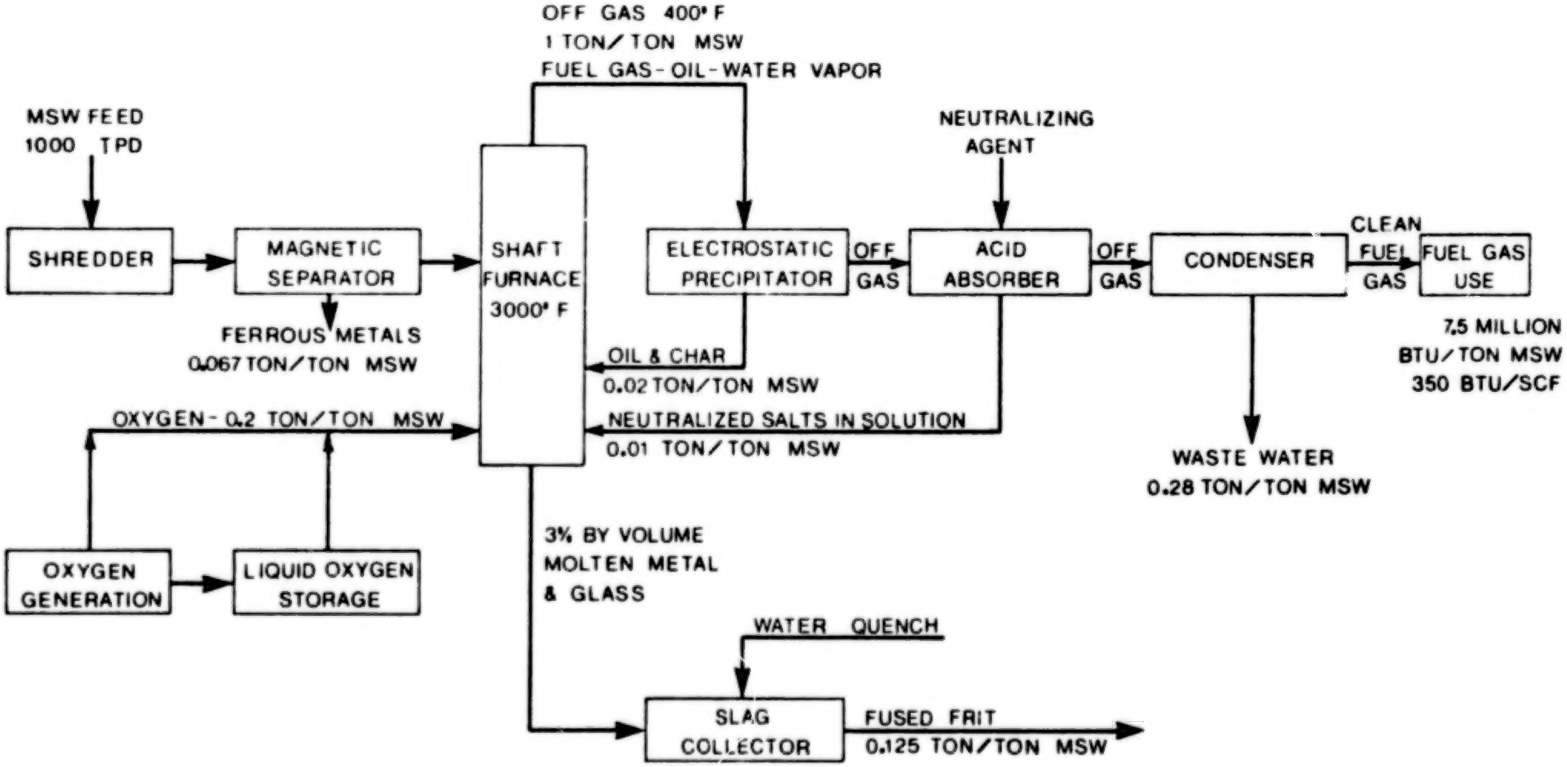

OFF GAS 400° F
1 TON/TON MSW
FUEL GAS-OIL-WATER VAPOR
MSW FEED
1000 TPD
SHREDDER
MAGNETIC SEPARATOR
FERROUS METALS
0.067 TON/TON MSW
SHAFT FURNACE 3000° F
ELECTROSTATIC PRECIPITATOR
OFF GAS
NEUTRALIZING AGENT
ACID ABSORBER
OFF GAS
CONDENSER
CLEAN FUEL GAS
FUEL GAS USE
7.5 MILLION
BTU/TON MSW
350 BTU/SCF
OIL & CHAR
0.02 TON/TON MSW
NEUTRALIZED SALTS IN SOLUTION
0.01 TON/TON MSW
WASTE WATER
0.28 TON/TON MSW
OXYGEN - 0.2 TON/TON MSW
OXYGEN GENERATION
LIQUID OXYGEN STORAGE
3% BY VOLUME
MOLTEN METAL
& GLASS
WATER QUENCH
SLAG COLLECTOR
FUSED FRIT
0.125 TON/TON MSW

Figure 4.- Oxygen-fed slagging pyrolysis.

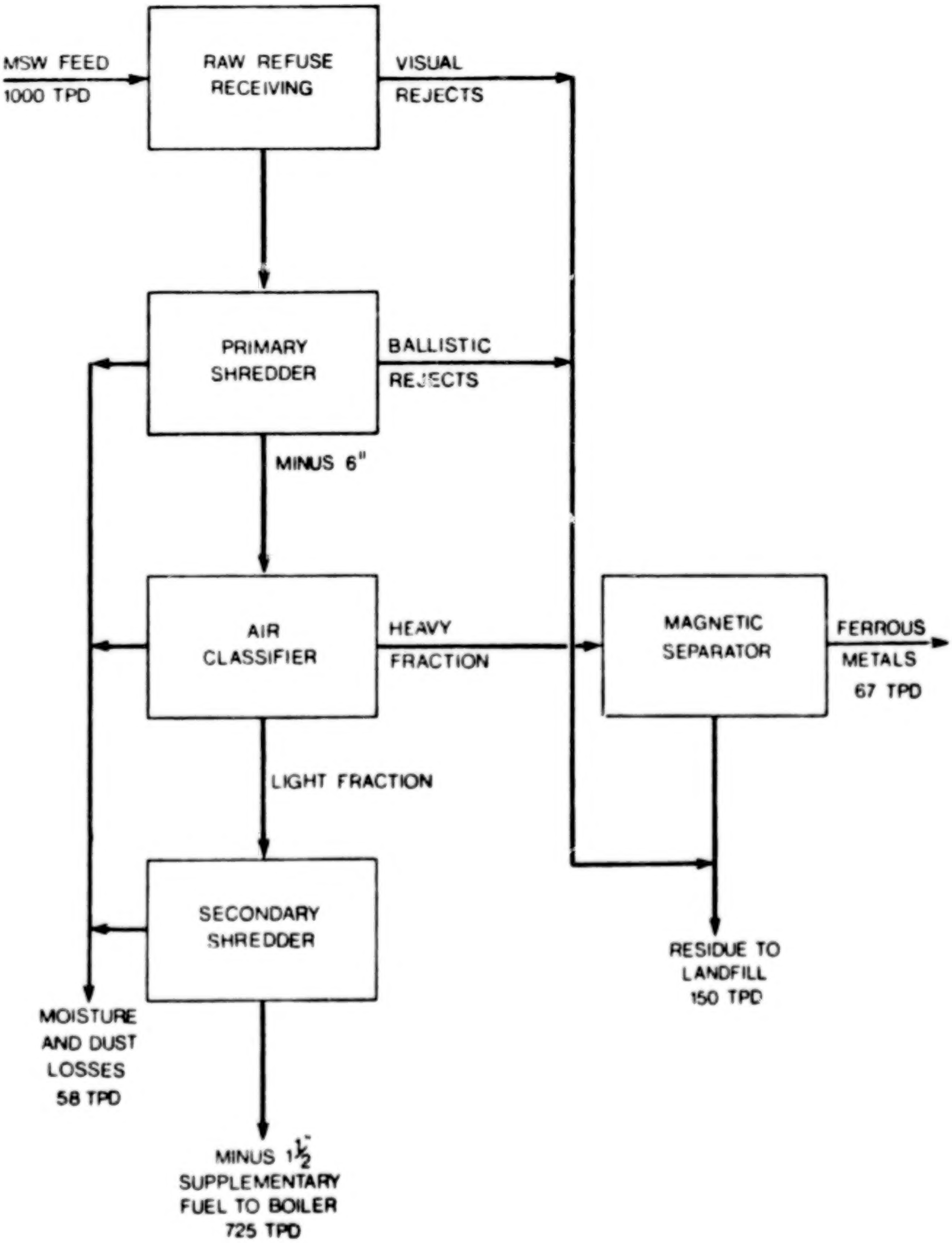

MSW FEED
1000 TPD
RAW REFUSE RECEIVING
VISUAL REJECTS
PRIMARY SHREDDER
BALLISTIC REJECTS
MINUS 6"
AIR CLASSIFIER
HEAVY FRACTION
MAGNETIC SEPARATOR
FERROUS METALS 67 TPD
LIGHT FRACTION
SECONDARY SHREDDER
RESIDUE TO LANDFILL 150 TPD
MOISTURE AND DUST LOSSES 58 TPD
MINUS 1½" SUPPLEMENTARY FUEL TO BOILER 725 TPD

Figure 5.- Co-combustion of shredded refuse.

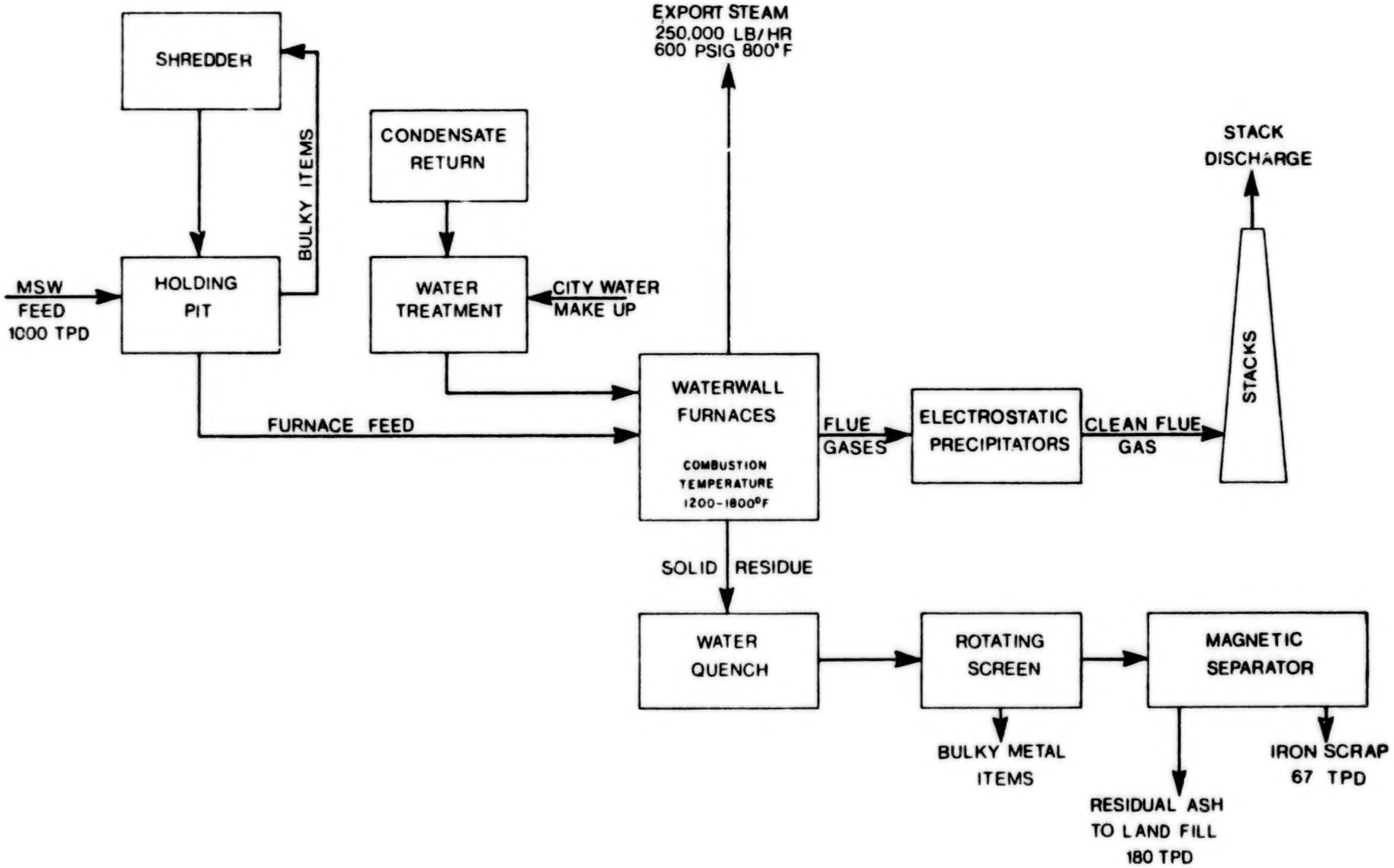

SHREDDER
BULKY ITEMS
MSW
FEED
1000 TPD
HOLDING
PIT
CONDENSATE
RETURN
WATER
TREATMENT
CITY WATER
MAKE UP
EXPORT STEAM
250,000 LB/HR
600 PSIG 800° F
STACK
DISCHARGE
STACKS
FURNACE FEED
WATERWALL
FURNACES
COMBUSTION
TEMPERATURE
1200-1800°F
FLUE
GASES
ELECTROSTATIC
PRECIPITATORS
CLEAN FLUE
GAS
SOLID RESIDUE
WATER
QUENCH
ROTATING
SCREEN
MAGNETIC
SEPARATOR
BULKY METAL
ITEMS
RESIDUAL ASH
TO LAND FILL
180 TPD
IRON SCRAP
67 TPD

Figure 6.- Waterwall boilers with resource recovery.

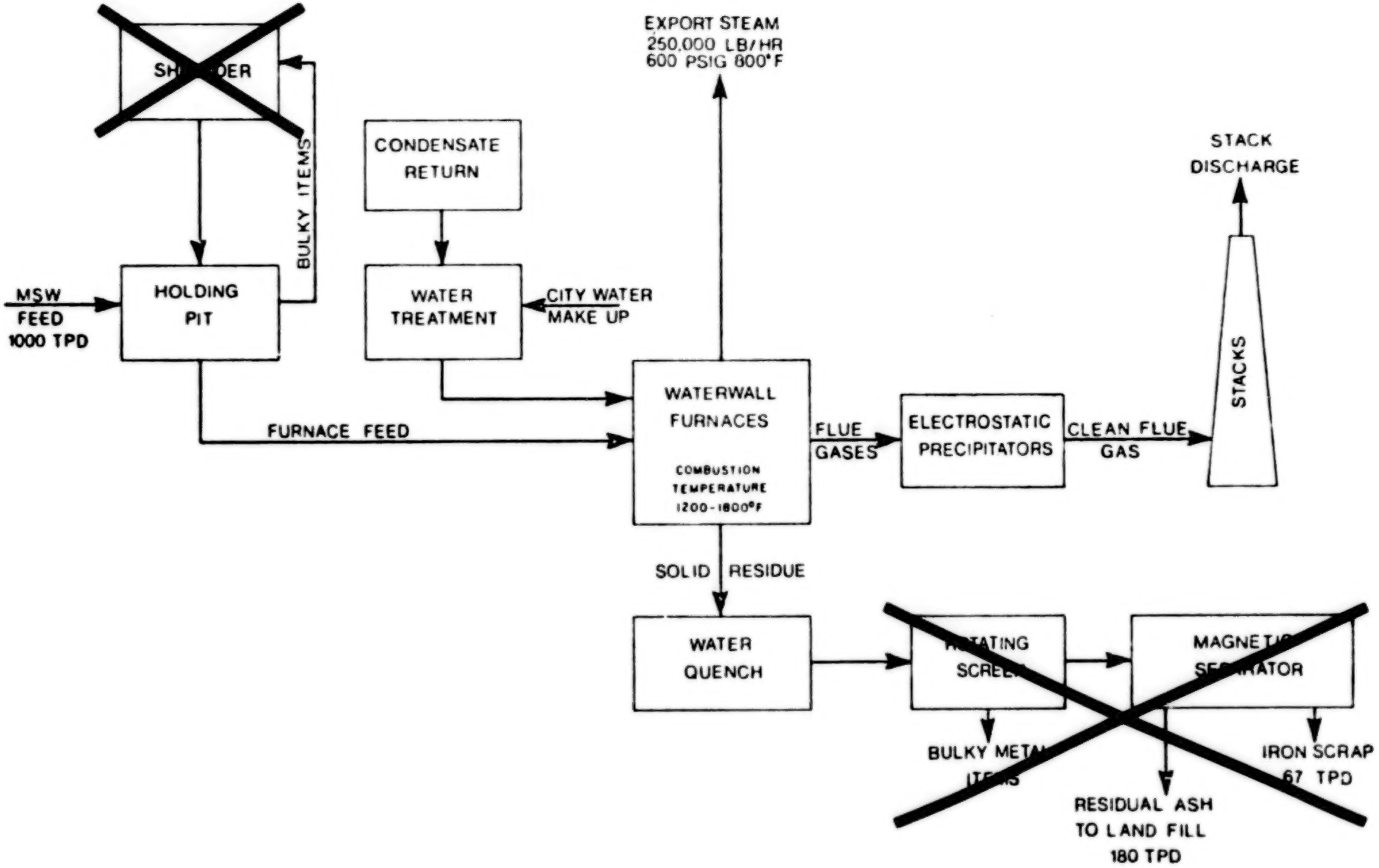

SHREDDER
BULKY ITEMS
MSW FEED 1000 TPD
HOLDING PIT
CONDENSATE RETURN
WATER TREATMENT
CITY WATER MAKE UP
EXPORT STEAM 250,000 LB/HR 600 PSIG 800°F
FURNACE FEED
WATERWALL FURNACES
COMBUSTION TEMPERATURE 1200-1800°F
FLUE GASES
ELECTROSTATIC PRECIPITATORS
CLEAN FLUE GAS
STACKS
STACK DISCHARGE
SOLID RESIDUE
WATER QUENCH
ROTATING SCREEN
MAGNETIC SEPARATOR
BULKY METAL ITEMS
RESIDUAL ASH TO LAND FILL 180 TPD
IRON SCRAP 67 TPD

Figure 7.- Waterwall boilers without resource recovery.

ONE STEP AT A TIME ....

- EMPLOY COMPETENT ENGINEERING FIRM TO:
  - IDENTIFY ENERGY CUSTOMER(S)
  - SELECT APPROPRIATE SYSTEM
  - CONDUCT ECONOMIC ANALYSIS

Figure 8.- Steps to solution.

FUEL SUPPLY VS. ENERGY DEMAND

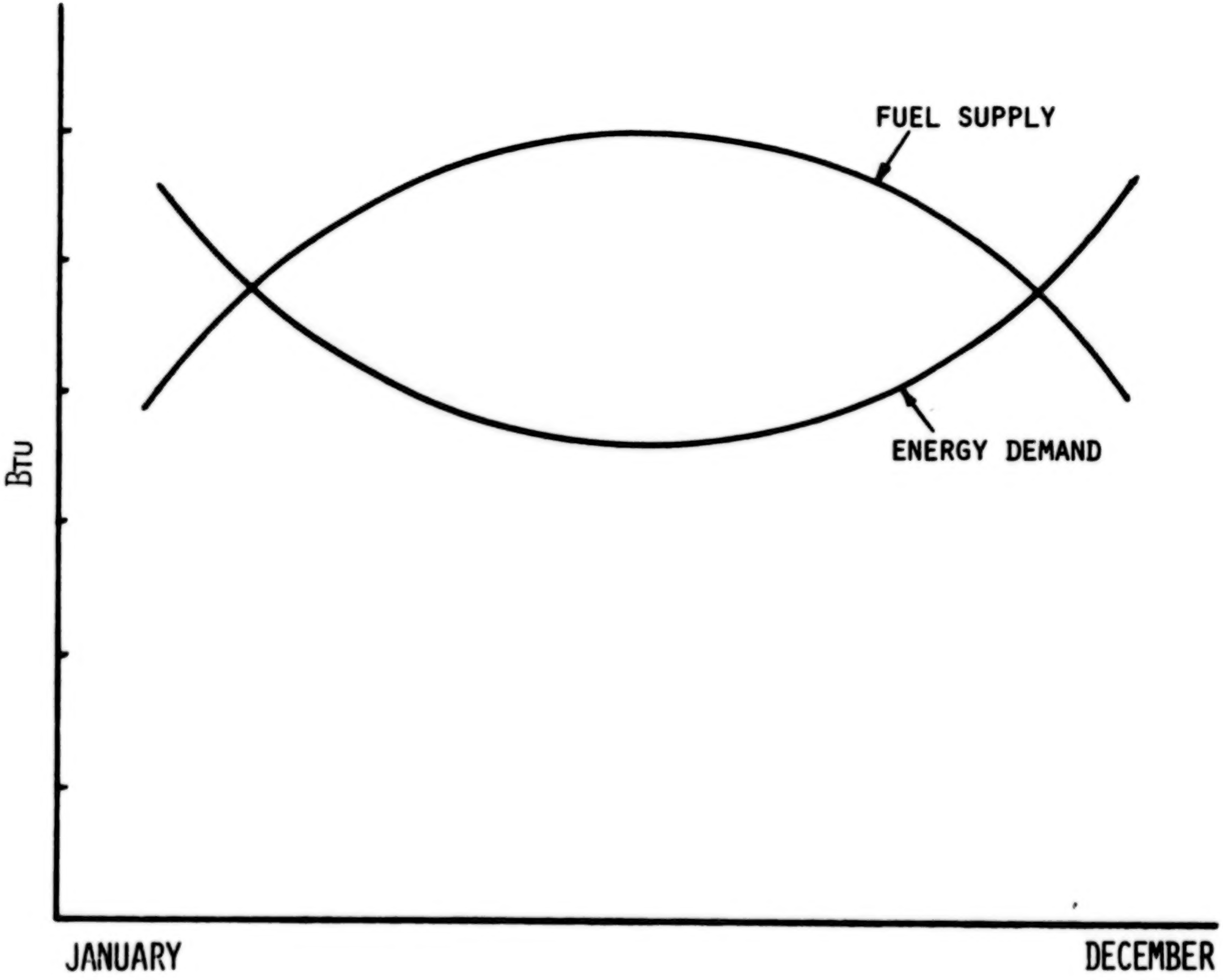
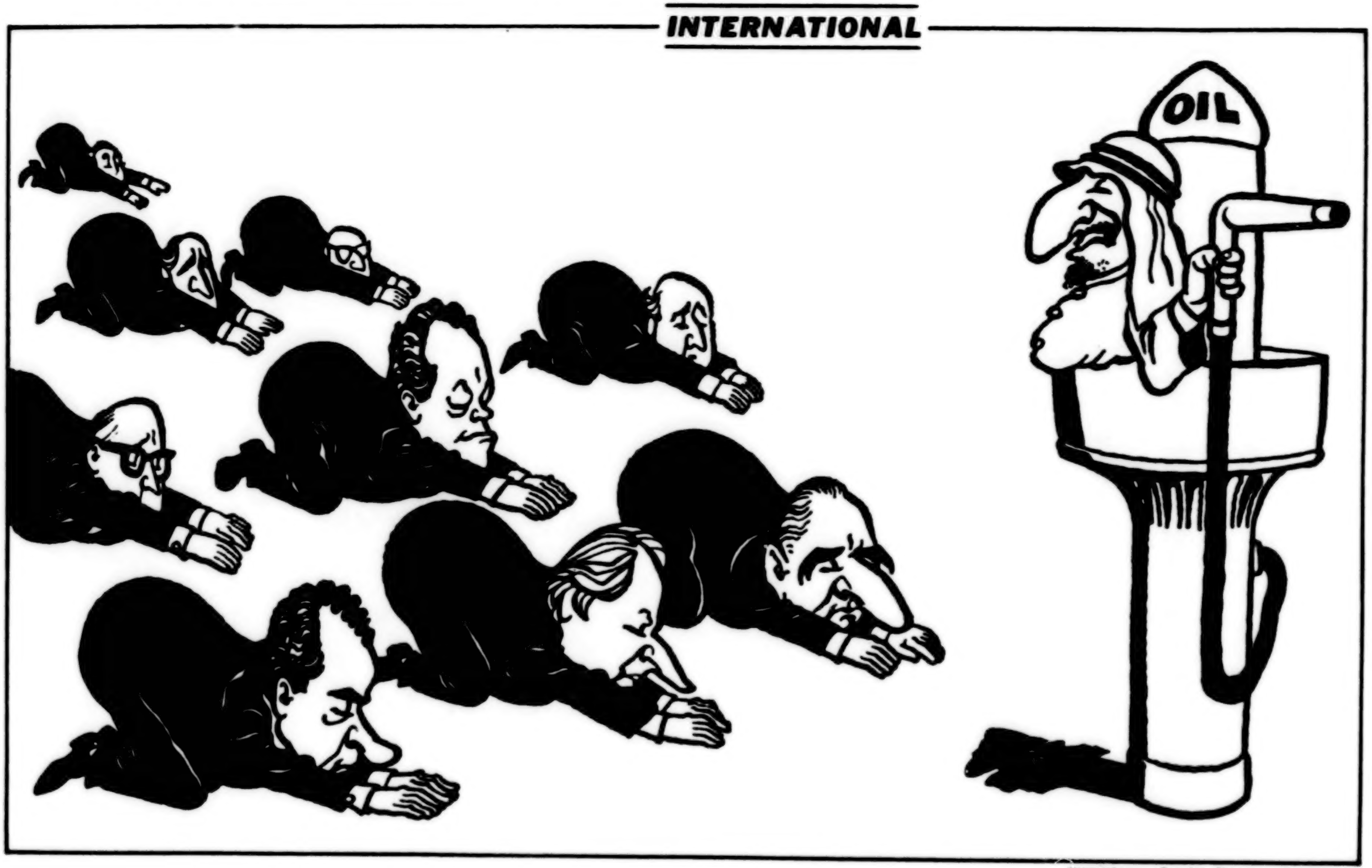


Figure 9.- Fuel supply compared with energy demand.


INTERNATIONAL
OIL

Cummings—Sunday Express, London

Samson Shakes the Temple

Figure 10.- Dependence on imported energy.

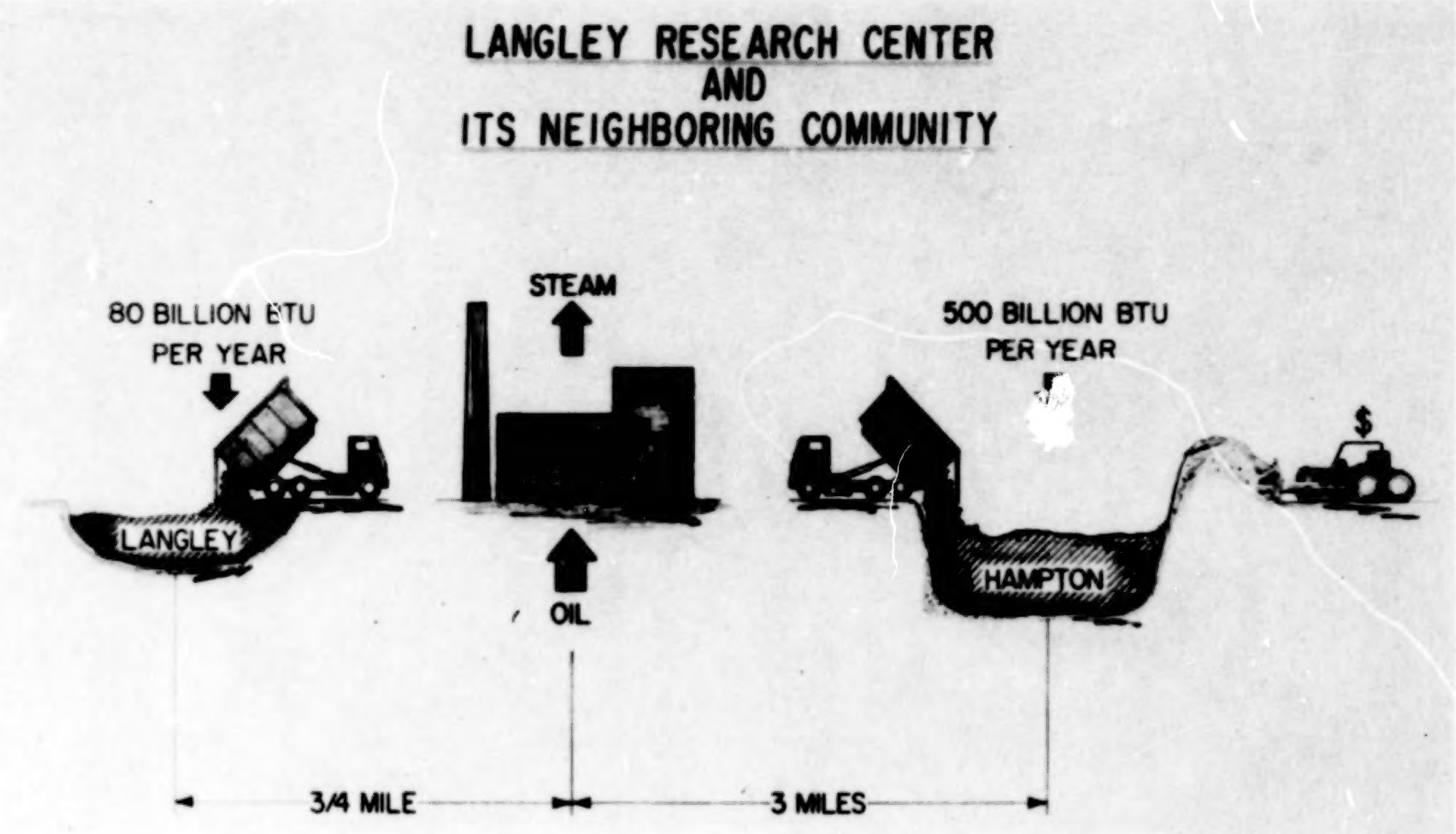
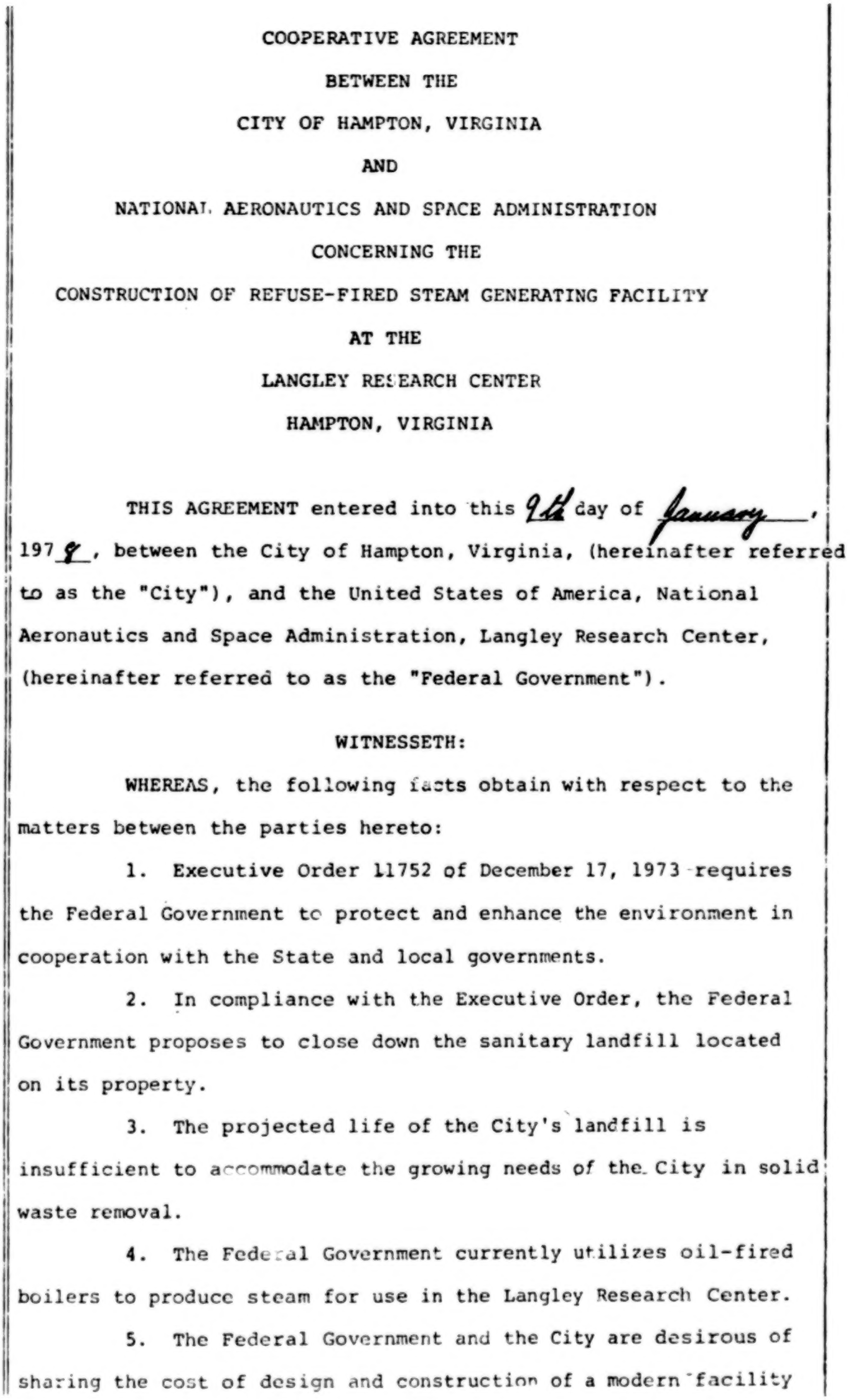

LANGLEY RESEARCH CENTER
AND
ITS NEIGHBORING COMMUNITY
80 BILLION BTU
PER YEAR
STEAM
500 BILLION BTU
PER YEAR
$
LANGLEY
OIL
HAMPTON
3/4 MILE
3 MILES

Figure 11.- Refuse/Energy picture for Langley Research Center and its neighboring community.



COOPERATIVE AGREEMENT
BETWEEN THE
CITY OF HAMPTON, VIRGINIA
AND
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
CONCERNING THE
CONSTRUCTION OF REFUSE-FIRED STEAM GENERATING FACILITY
AT THE
LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA

THIS AGREEMENT entered into this 9th day of January, 1978, between the City of Hampton, Virginia, (hereinafter referred to as the "City"), and the United States of America, National Aeronautics and Space Administration, Langley Research Center, (hereinafter referred to as the "Federal Government").

WITNESSETH:

WHEREAS, the following facts obtain with respect to the matters between the parties hereto:

1. Executive Order 11752 of December 17, 1973 requires the Federal Government to protect and enhance the environment in cooperation with the State and local governments.

2. In compliance with the Executive Order, the Federal Government proposes to close down the sanitary landfill located on its property.

3. The projected life of the City's landfill is insufficient to accommodate the growing needs of the City in solid waste removal.

4. The Federal Government currently utilizes oil-fired boilers to produce steam for use in the Langley Research Center.

5. The Federal Government and the City are desirous of sharing the cost of design and construction of a modern facility

Figure 12.- Cooperative agreement.

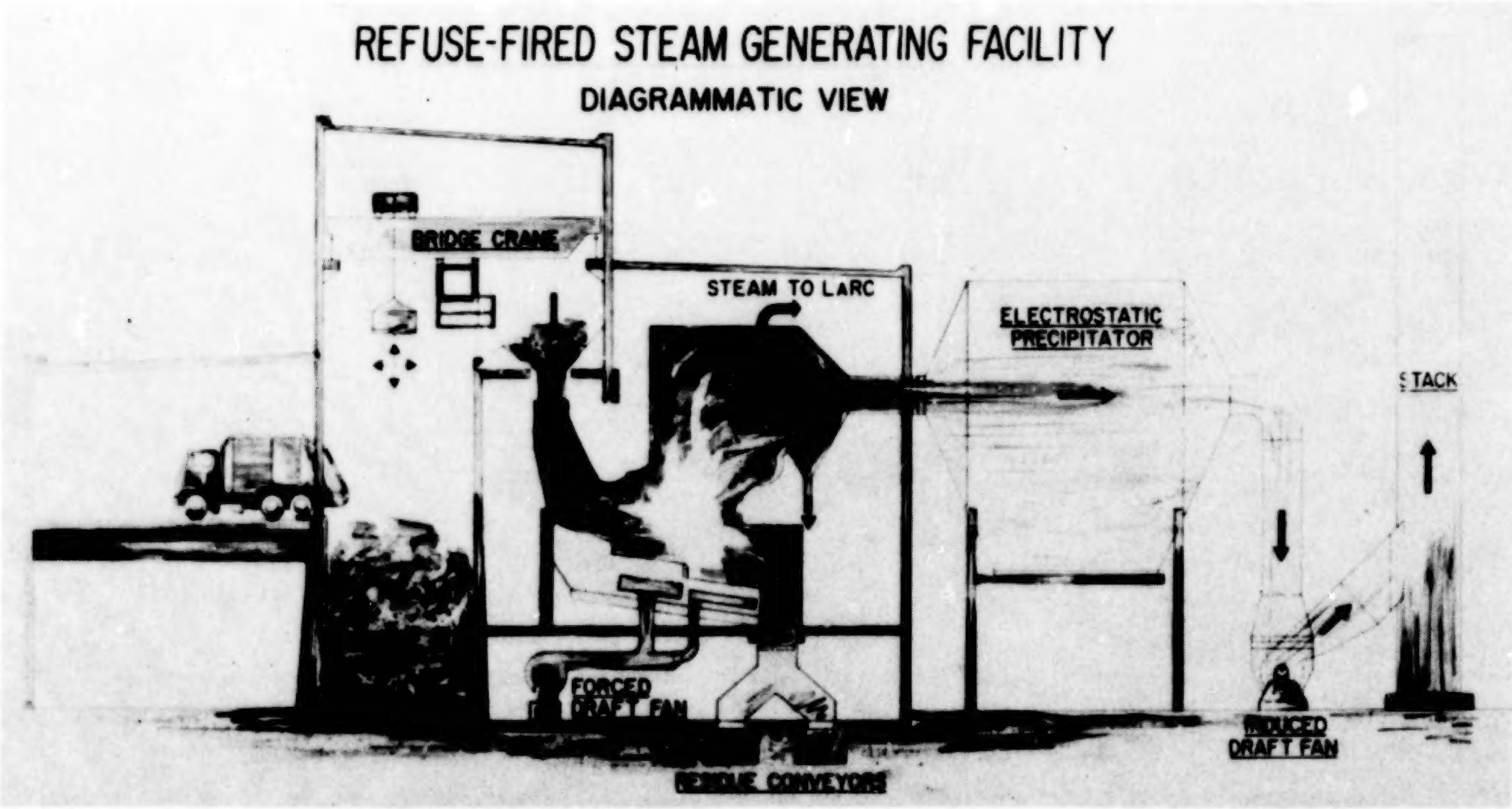

REFUSE-FIRED STEAM GENERATING FACILITY
DIAGRAMMATIC VIEW
BRIDGE CRANE
STEAM TO LaRC
ELECTROSTATIC PRECIPITATOR
STACK
FORCED DRAFT FAN
INDUCED DRAFT FAN
RESIDUE CONVEYORS

Figure 13.- Diagrammatic view of refuse-fired steam generating facility.

FUEL SOURCE	PARTICULATES	SULFUR OXIDES	CARBON MONOXIDE	HYDROCARBONS	NITROGEN OXIDES
EXISTING					
REFUSE	-	-	-	-	-
FUEL OIL	30,472	533,254	5,540	2,878	106,374
PROPOSED					
REFUSE	20,894	58,038	69,646	34,823	69,646
FUEL OIL	8,126	142,201	1,477	1,034	28,366
TOTAL	29,020	200,239	71,123	35,857	98,012
NET CHANGE	-1,452	-333,015	66,583	31,979	-8,362
PERCENT CHANGE	-4.8	-62.4	1,184	825	-7.9

Figure 14.- Total annual stack emissions from proposed and existing boiler facilities, in kg.

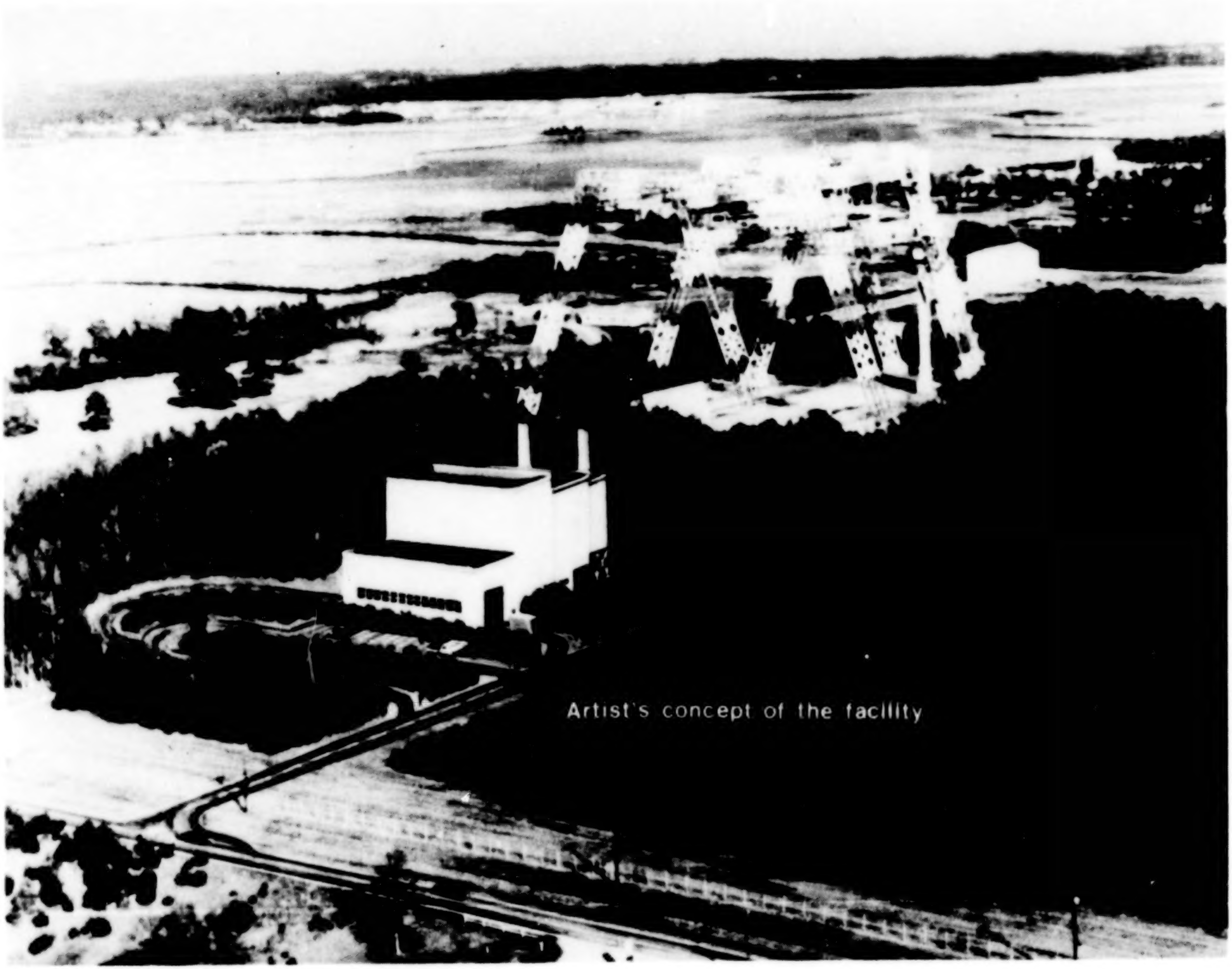

Artist's concept of the facility

Figure 15.- Artists' concept of facility.

BENEFITS

- SAVES ENOUGH FUEL TO HEAT 2500 HOMES (2,400,000 GALS/YR)
- ENHANCES THE ENVIRONMENT
- CONSERVES LANDFILL AREA

Figure 16.- Benefits to the community.

HOW MUCH ENERGY DOES ENERGY COST?

Warren D. Devine, Jr.
Institute for Energy Analysis
Oak Ridge Associated Universities

SUMMARY

Estimating the energy cost of producing and delivering an energy product involves the quantitative determination of all relevant energy flows and the aggregation of these flows into meaningful indices of system performance. Five emerging energy technologies are subjected to energy analysis. The energy delivered by each is substantially greater than the energy consumed during construction and lifelong operation of the system. Net energy analysis can provide interesting and perhaps useful information regarding specific technologies, but it does not necessarily provide additional information essential to the making of decisions regarding those technologies.

INTRODUCTION

Public Law 93-577, the Nonnuclear Energy Research and Development Act of 1974, stipulates that in assessments of prospective energy supply technologies by the Energy Research and Development Administration (and now, presumably, by the Department of Energy) "the potential for production of net energy by the proposed technology at the stage of commercial development shall be analyzed and considered in evaluating proposals". Thus the Congress of the United States is interested in seeing that the energy cost of energy from emerging technologies be estimated prior to large scale commitment to these technologies. The studies summarized in this paper were performed at the Institute for Energy Analysis in early 1977 for the Assistant Administration for Planning, Analysis, and Evaluation of the Energy Research and Development Administration. The work is reported in detail in Reference 1. All but one of the energy systems studied are of potential use somewhere in the Southeastern United States.

Net energy is defined herein as the energy remaining for use outside an energy system after deducting from the gross output of the system all of the energy required for constructing and operating the system except for the energy content of the primary energy resource being processed. Thus, we seek to identify fully and completely all of the energy costs of supplying energy by a given method. These energy costs are not limited to those incurred by or for the energy system being analyzed; they also include energy costs incurred elsewhere in society as a necessary result of constructing and operating the energy system. The Institute for Energy Analysis has developed guidelines for conducting such a net energy analysis (Reference 2). These guidelines have been applied in the present work to an ocean thermal energy conversion system, a wind energy conversion system used for fuel displacement, in situ oil shale processing, the combustion of coal in fluidized beds, and municipal solid waste disposal.

METHODOLOGY

Net energy analysis consists of two steps: the quantitative determination of all relevant energy flows and the aggregation of these flows into appropriate indices of system performance. The first step generally requires the vast majority of the effort devoted to an energy analysis.

Energy expenditures may be classified as direct or indirect. Direct energy expenditures include all fuels and electricity used in each stage of facility construction and operation. Noncommercial forms of energy (e.g., solar radiation or wind) are not counted as energy costs. Indirect energy expenditures include energy embodied in the system components and in materials used during construction and operation. They also include a pro rata share of the energy embodied in the capital equipment that produces these components and materials and in the equipment utilized during the construction process. In addition, we include the energy associated with producing the fuels and electricity that are directly consumed.

Net energy analysis of an energy supply or conservation system concentrates on a particular sequence of process steps called a *trajectory*. The analyst begins with a specified energy source and follows it through sequential stages of extraction, processing, and transportation to ultimate delivery. The specification of a trajectory requires determining system boundaries, i.e., which processes and activities are to be included. Horizontal boundaries define the sequence of consecutive process stages to be included in the trajectory. For those technologies considered here, the trajectory begins with the resource in place and ends with the production or delivery of an energy product. Vertical boundaries define the hierarchy of energy inputs to be included in the analysis of each process stage. As shown in Figure 1, these inputs can, in principle, be traced back indefinitely. We have drawn these boundaries to include all the direct and indirect energy which can, in principle, be captured in interindustry input-output coefficients, as discussed below. This implies that the energy included in the accounts for a particular process stage is associated with activities undertaken purposely on behalf of the energy system or its suppliers and which would not otherwise be done. Thus, for example, ordinary private energy consumption by employees of energy facilities (including routine transportation to and from work) is not included in the accounts; comparable consumption would occur regardless of the existence of the energy system under study.

Relevant energy flows can be estimated by processes analysis, by interindustry input-output analysis (I-O), or by a combination of the two techniques. Figure 2 outlines the steps toward estimating the energy embodied in a capital facility. The common, essential element is a complete and accurate description of the process, including a detailed bill of materials.

We can then analyze the specific manufacturing industries that produce the components of the facility in question, or we can employ I-O analysis. The former path can be extremely laborious and hypothetical when dealing with new technologies and industrial processes. The conceptual basis for the latter path is described in Reference 2. Suffice it to say here that the I-O method employs a set of energy intensity coefficients for 357 sectors of the U.S. economy and, usually, cost estimates for items assigned to a number of these sectors. One of the difficulties of using this approach to analyze developing energy technologies is, of course, that some of the components of the process in question may not fit into any of the 357 sectors. Another difficulty is that component cost estimates for developing technologies are often very poor.

We have carefully considered both of these potential difficulties and have developed an alternate path within the I-O approach. This path involves estimates of sector average prices and component weights. Although less direct than process analysis, one advantage of the I-O approach is that the energy intensity coefficients, in principle, include all of the direct and indirect energy associated with the output of the sector, regardless of the route this energy travels through the economy.

Energy intensity coefficients in physical units (joules of primary energy required per kilogram of product) have been developed by Reister (Reference 4) using earlier work by Bullard et al. (Reference 5). Table 1 presents the coefficients for three Standard Industrial Classification industry groups. (This classification system is described in Reference 6.) Note that products which require greater fabrication embody--as one would intuitively expect--greater energy. Of course these numbers are averages; considerable error must be expected when a component under question is not a "typical" product of the industry group to which it is assigned.

The question of net energy from developing technologies is necessarily tied to the characteristics of the industrial system within which the new technologies might play a role. However, substantial changes in the energy supply system, particularly in energy prices, will result in significant changes in industrial practice. Although it is extremely difficult to specify what these changes will be in the future, it is also difficult, due to delays in reporting, to tell precisely what they have been over the last 10 years. The only available and consistent set of energy intensity data is derived from 1967 industrial practices. Consequently, the energy expenditures are based on 1967 technology and energy use patterns. This implies that we are making our estimates at the margin of the 1967 economy; in effect, none of the supply systems or supporting industries is assumed large enough to perturb the existing data.

The second step of a net energy analysis is the aggregation of the energy flows into some index of system performance. Net energy is the energy remaining for use outside the energy system after deducting the total primary energy embodied in the system and in that required by the system for operation and maintenance. As shown in Figure 3, net energy is the difference between the delivered energy product E_1 and the total primary energy subsidy T_s. Note that the energy content of the fuel or principal energy resource input I_o is not included in the subtrahend. We have chosen, however, to present the results not as an absolute value of net energy, but rather as a ratio. The most straightforward ratio, or index of system performance, is simply the "delivered product feedback ratio":

$$\mathrm{DPFR} = \frac{E_1}{T_s} = \frac{\text{Delivered energy product}}{\text{Total primary energy subsidy}} \qquad (1)$$

This ratio expresses the amount of energy product delivered to the trajectory end-point by the energy system per unit of fossil energy expended on it. Unfortunately, the real-world situation is more complicated than that depicted in Figure 3. All energy is not of the same form; a joule of energy in the form of heat from combustion of fossil fuel does not have the same utility as a joule of energy in the form of electricity. The more general case is discussed in Reference 2.

APPLICATION

Brief descriptions of five systems subjected to net energy analysis follow. The analytical trajectories are indicated, as well as particularly energy intensive components or operations. The wind energy conversion system described here is presently under construction in Boone, North Carolina; a more detailed description of this system and its energy analysis is provided in Reference 7. Of the five systems considered, only in situ oil shale processing is inapplicable to the Southeastern states.

OCEAN THERMAL ENERGY CONVERSION

System Description

Design: Lockheed Missiles and Space Company conceptual design.

Type: Rankine power cycle with ammonia working fluid and titanium heat exchangers, underwater dc transmission of electricity.

Location: tropical waters, 30 kilometers offshore.

Rated power: 160 MW(e) net.

Lifetime: 35 to 100 years, depending on specific component.

Average annual net station output: 1.26 x 10^9 kWh(e) with a plant factor of 90 percent.

Analytical Trajectory

From: thermal gradients in tropical oceans.

To: delivered electricity.

Facility is assumed to feed an electrical grid as a base-loaded power plant. Energy embodied in transmission lines is included in energy subsidy, and delivered electricity includes a 9-percent loss in transmission and distribution.

Most Energy Intensive Components or Operations

Four power modules consisting primarily of steel and titanium.

WIND ENERGY CONVERSION

System Description

Design: 1500 kW(e) Model One wind electric generating station designed by the General Electric Company for the ERDA wind energy program at NASA.

Type: horizontal-axis, two-blade rotor without storage; equipped for unattended operation.

Location: Boone, North Carolina.

Rated power: 1500 kW(e) net at 10 m/s wind speed.

Lifetime: 30 years.

Average annual net station output: 6.62 x 10^6kWh(e) with a utilization factor of approximately 50 percent.

Analytical Trajectory

From: energy contained in the wind.

To: delivered electricity.

Analysis assumes the facility is used only for fossil fuel displacement. Energy embodied in transmission and distribution lines is neglected in the energy subsidy, but delivered electricity includes a 9-percent loss between generating unit and consumer.

Most Energy Intensive Components or Operations

Open steel truss tower and mechanical transmission.

IN SITU OIL SHALE PROCESSING

System Description

Design: Fenix and Scisson, Inc., Room and Pillar Base Case Computer Run 40, prepared for the U.S. Bureau of Mines.
Type: room and pillar mining with vertical drill and blast (modified in situ process).
Location: Green River shale containing 0.08 liters oil per kilogram
Capacity: 8 million liters per day
Lifetime: 17.7 years.
Lifetime net output: 2×10^{18} joules (2 exajoules)

Analytical Trajectory

From: oil shale.
To: recovery of shale oil at surface.

Energy expenditure does not include processing or disposing of excavated shale nor prerefining oil to produce the equivalent of crude. No credit is taken for recovering oil in excavated shale or for by-product low-joule gas.

Most Energy Intensive Components or Operations

Electricity and diesel fuel consumed during mine operation.

FLUIDIZED BED COAL COMBUSTION

System Description

Design: General Electric Company, ECAS Phase II.
Types: atmospheric fluidized-bed (AFB) and pressurized fluidized-bed (PFB) advanced steam cycle systems are compared with a conventional coal steam system (CONV) with stack gas scrubbers.
Location: none specified.
Rated power: results for each system normalized to 747 MW(e) net.
Lifetime: 30 years.
Average annual net station output: 4.25×10^9 kWh(e) with a plant factor of 65 percent.

Analytical Trajectory

From: coal in mine.
To: delivered electricity.

Analysis assumes plants are used for central station electricity generation. Energy embodied in transmission and distribution lines is neglected in the energy subsidy, but delivered electricity includes a 9-percent loss between central station and consumer.

Most Energy Intensive Components or Operations

Annual operating energies are four to five times greater than the annualized capital energies.

MUNICIPAL SOLID WASTE DISPOSAL

System Description

Design: Tennessee Valley Authority feasibility study.
Type: use of processed municipal solid waste as a substitute electric power plant fuel, energy-intensive residuals recovered from processing stage.
Location: East Tennessee.
Capacity: 1.8 million kilograms of raw solid waste per day.
Lifetime: 20 years for major waste handling facilities.
Total energy saved: 12.9 x 10^6 joules per kilogram of raw solid waste.

Analytical trajectory

From: raw municipal solid waste.
To: energy savings from reduced coal consumption in electric power production, from recovery of energy-intensive materials, and from reduced disposal of unprocessed waste.

The solid waste processing system is viewed as an energy conservation rather than an energy supply system.

Most Energy Intensive Components or Operations

Processing of solid waste and operation of steam plant.

RESULTS

Indices of performance calculated for the five energy systems are displayed in Table 2. Since the solid waste disposal system is viewed as an energy conservation system, an appropriate index is the "conservation feedback ratio" (CFR) defined in the table. Note that the energy delivered or saved by each of the technologies is substantially greater than the energy consumed during construction and lifelong operation of the system.

The total primary energy subsidy of all but one system has been disaggregated into that portion used for the generation and delivery of the electrical energy subsidy and that portion used directly for the thermal energy subsidy. The results are shown in Table 3. Only in the case of the oil shale retort is the majority of the subsidy utilized to provide needed electricity. This underscores the electrical energy intensity of the mining operations, which require fans and blowers for air circulation and to support the descending combustion front.

The energy expenditures associated with deploying and operating the capital equipment are also disaggregated and shown in Table 3. The former category includes the energy embodied in the components themselves (both direct and indirect) and the energy consumed during construction; it may also include energy expended during design and site delivery of the components. The latter category includes all of the direct and indirect energy expended for maintaining and operating the energy facility. Note that the two technologies which utilized indirect solar energy (the ocean and wind systems) have far more of their subsidy embodied in capital equipment than in operations. The reverse is true for the other technologies, which are based upon nonrenewable resources.

DISCUSSION

Intercomparison of Energy Ratios

The five systems analyzed herein provide several examples of the caution that must be exercised when one is tempted to compare one system with another on the basis of net energy ratios.

System Purpose. The only function of the first four systems considered is the generation of an energy product. On the other hand, the primary function of the fifth system is not to provide an energy product but to dispose of municipal solid waste; the substantial amount of energy saved is a secondary result of using the system. This basic difference is reflected in the preparation of the energy accounts. The solid waste system is one that builds upon an existing waste collection system and upon an existing coal-fueled power plant. Thus, the energy embodied in these major components has not been included in the energy accounts for the system. The incremental energy subsidy includes only the difference in energy expenditure between this system and a conventional waste disposal system. Since we are not counting *all* the energy embodied in the solid waste system, and since we are not evaluating the output of the system in terms of a delivered energy product, the ratios are not the same by definition. Obviously, then, we cannot generally compare conversion and conservation systems on the basis of these ratio values. Under certain conditions, however, such as identical applications and trajectory endpoints, we can compare conversion and conservation systems in answer to a specific question such as: Does it take more energy to conserve a unit of energy with system A or to generate an additional unit of energy with system B? Of course, the energy ratio we have defined for conservation systems can be of interest by itself if energy conservation and not economic viability is the primary goal. In this case the conservation ratio can serve as a useful guide to system design, for one would certainly avoid systems for which the ratio approaches unity.

System Application. Of the four energy conversion systems considered here, three produce electricity. Alternatively, we can say that their energy supply trajectories terminate at the same point. Nevertheless, the values of the energy ratios for these systems cannot all be compared because their *applications* are not identical. The ocean thermal energy and coal conversion systems stand alone and generate base-load electricity. The wind energy conversion system, on the other hand, generates electricity only when the wind speed is within a specific range, and when it is used it displaces fossil fuel in an electric utility system. If the wind system were modified to generate base-load energy, substantial storage capacity would be required. This addition could significantly alter the energy ratio, perhaps lowering it to the range 5-10 shared by the other systems. We believe it is possible to state that while essentially the same load-duration curves are *necessary* for energy ratio comparisons, they are *insufficient* for valid comparisons.

System Trajectory. The trajectories of the energy systems considered do not terminate at the same point: three extend through the transmission and distribution of electricity, one terminates with the production of shale oil, and one terminates with the saving of primary energy. It is not valid to compare energy ratios for systems whose trajectories do not share a common endpoint, such as ocean thermal energy conversion and in situ oil shale processing. Any attempt to make such a comparison implies that weight factors have been assigned to the output of the systems involved. To continue the example, direct comparison of the yield ratios for the ocean thermal and oil shale systems implies that weight factors of unity have been assigned; i.e., the observer equates the value of delivered electricity to that of shale oil at the mine site.

In general, then, one cannot compare dissimilar energy technologies on the basis of net energy ratios. On the other hand, it is at least valid to make such comparisons when the systems have identical purposes, applications, and trajectory endpoints. Even under these conditions, however, the several ways of viewing the energy yield versus the energy subsidy (i.e., the various energy ratios) and the intrinsic uncertainties in the computations (about 30%) must be considered during the comparison.

Energy Ratios and Resource Requirements

Energy accounting requires that the analyst explicitly define the system being analyzed—its purpose, application, boundaries, and trajectory, and the energy ratios pertaining to it. Nevertheless, the value of these ratios can still be somewhat arbitrary, while the actual energy resources required to deliver a unit of energy may be more invariant. For example, the greatest difference among the three coal combustion systems analyzed is the heating value of the coal used to operate the calciner in the conventional system. While it seems reasonable to regard this energy as an operating input (and thus as part of the energy subsidy), one could also argue that this energy should be regarded as part of the principal energy input to the plant along with the boiler fuel. The decision to allocate this energy as a subsidy or, alternatively, as part of the principal energy input, has no effect whatever on the resource requirements per unit of electricity delivered to consumers. It does, however, significantly affect the computed energy ratios.

Another example involves retorting oil shale in place versus in an above ground retort. For the in situ system, a certain fraction of the resource is consumed in retorting or otherwise not recovered from the retort zone and does not enter the energy account. For an above ground retort, however, some part of this energy appears in the subsidy accounts as heat required for retorting. Both the resource affected and energy yield could be virtually unchanged, while the ratio could change drastically in going from the in situ to the above ground method of recovery.

A clear distinction must therefore be made between the question of net energy (How much of the *gross* output of the energy supply system must be used to construct and operate the system itself?) and the question of resource requirements (How much raw energy resource is consumed—or otherwise made unavailable for future use—per unit of *net* output of the supply system?). Obviously, net energy and resource utilization are closely related, but not identical, aspects of energy analysis. Figure 4 illustrates this distinction for the in situ retorting of oil shale.

Net Energy Analysis and Engineering Economic Analysis

We have utilized energy accounting to identify and compute the energy flows in society that are needed to deliver energy in a particular form. The analytical procedure itself can provide a deeper and more explicit understanding of the dependence of energy-producing technologies on energy-intensive sectors of the economy. This understanding can aid in identifying system components that might be especially sensitive to energy price and availability and in assessing whether conditions might exist whereby the energy yield from a particular technology would fail to be substantially greater than the energy subsidy. However, such a failure should contribute to an unfavorable engineering economic analysis as well.

There are, of course, many factors governing the feasibility and acceptability of energy supply and conservation systems. Energy analysis can provide information about two of these factors: net energy yield and energy resource requirements. The energy delivered by each of the emerging technologies considered here is substantially greater than the energy consumed during construction and lifelong operation of the system. Therefore, if each of these technologies can be economically justified, we see no reason to discourage any of them on the basis of net energy yield. Although our studies have not demonstrated that net energy analysis necessarily provides additional, essential information to the decision making process, it is possible to regard the net energy estimate as a screening test. In this case, the systems considered here clearly pass, and decisions to proceed with development and deployment should be based on other considerations.

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3. A. G. Melcher, et al.: "Net Energy Analysis: An Energy Balance Study of Selected Fuel Technologies". Colorado Energy Research Institute, Golden, Colorado, 1976.

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5. C. W. Bullard, P. S. Penner, and D. A. Pilati: "Energy Analysis Handbook". Center for Advanced Computation, CAC Document 214, University of Illinois, Urbana, Illinois, 1976.

6. U.S. Technical Committee on Industrial Classification, Standard Industrial Classification Manual for 1972. U.S. Government Printing Office, Washington, D.C., 1974.

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TABLE 1: ENERGY INTENSITY COEFFICIENTS

SIC	Name	Price ($/kg)	Total Primary Energy Intensity* (10^6 joules/dollar)	Total Primary Energy Intensity (10^6 joules/kg)
3441	Fabricated Structural Steel	0.40	144.6	58.3
3443	Fabricated Platework	1.06	122.0	129.2
3566	Mechanical Power Transmission Equipment	2.45	69.7	170.5

*Total primary energy is, by convention, the sum of coal, crude oil and crude natural gas, and the fossil energy equivalent of hydro- and nuclear-electricity.

TABLE 2: NET ENERGY INDICES

Energy System	DPFR (Delivered energy product : Total primary energy subsidy)	CFR (Total energy saved : Incremental primary energy subsidy)
Ocean Thermal	6.6	
Wind-Fuel Displacement	40.	
In Situ Oil Shale	8.6	
Fluidized-Bed Combustion		
AFB	7.2	
PFB	6.8	
CONV	4.7	
Municipal Waste Disposal		10.5

TABLE 3: DISTRIBUTION OF TOTAL PRIMARY ENERGY SUBSIDY

	% Electricity	% Heat	% Capital	% Operating
Ocean Thermal	37	63	84	16
Wind-Fuel Displacement	27	73	~100	0
In Situ Oil Shale	59	41	4	96
Fluidized-Bed Combustion				
AFB	13	87	15	85
PFB	15	85	19	81
CONV	9	91	13	87
Municipal Waste Disposal			13	87

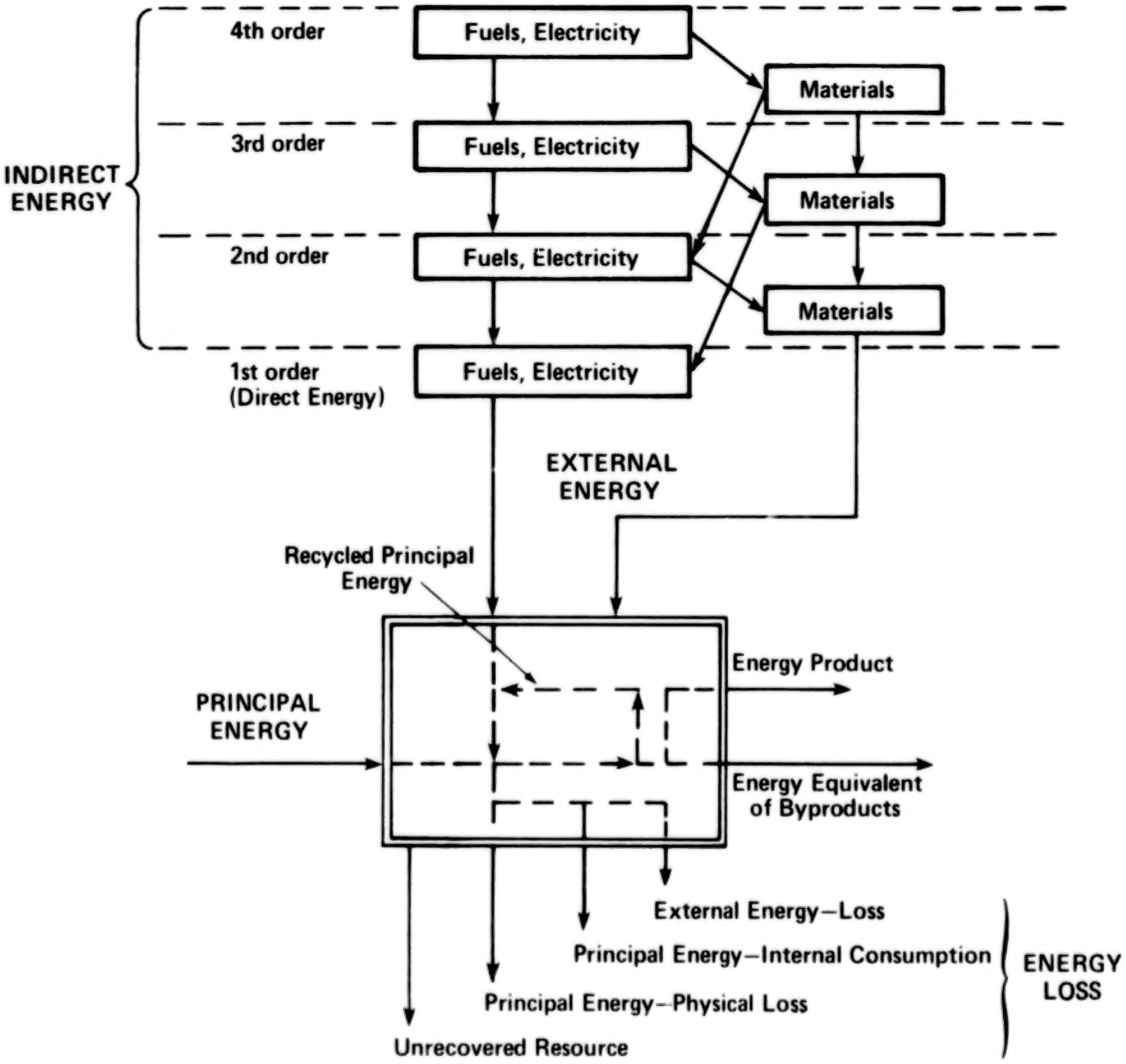
INDIRECT ENERGY
4th order
3rd order
2nd order
1st order (Direct Energy)
Fuels, Electricity
Fuels, Electricity
Fuels, Electricity
Fuels, Electricity
Materials
Materials
Materials
EXTERNAL ENERGY
Recycled Principal Energy
PRINCIPAL ENERGY
Energy Product
Energy Equivalent of Byproducts
External Energy—Loss
Principal Energy—Internal Consumption
Principal Energy—Physical Loss
Unrecovered Resource
ENERGY LOSS

Figure 1.- Hierarchy of energy flows. (Source: ref. 3)

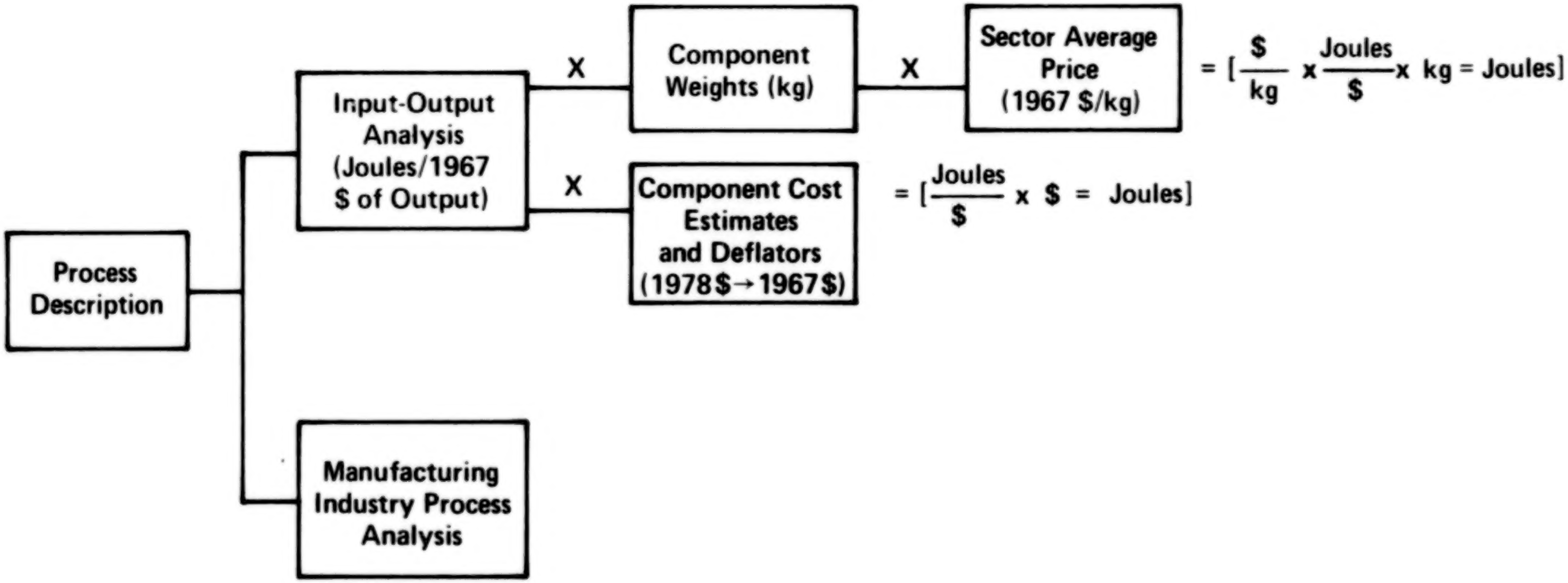
Process Description
Input-Output Analysis (Joules/1967 $ of Output)
X
Component Weights (kg)
X
Sector Average Price (1967 $/kg)
= [$ / kg x Joules / $ x kg = Joules]
X
Component Cost Estimates and Deflators (1978$→1967$)
= [Joules / $ x $ = Joules]
Manufacturing Industry Process Analysis

Figure 2.- Approaches to energy analysis.

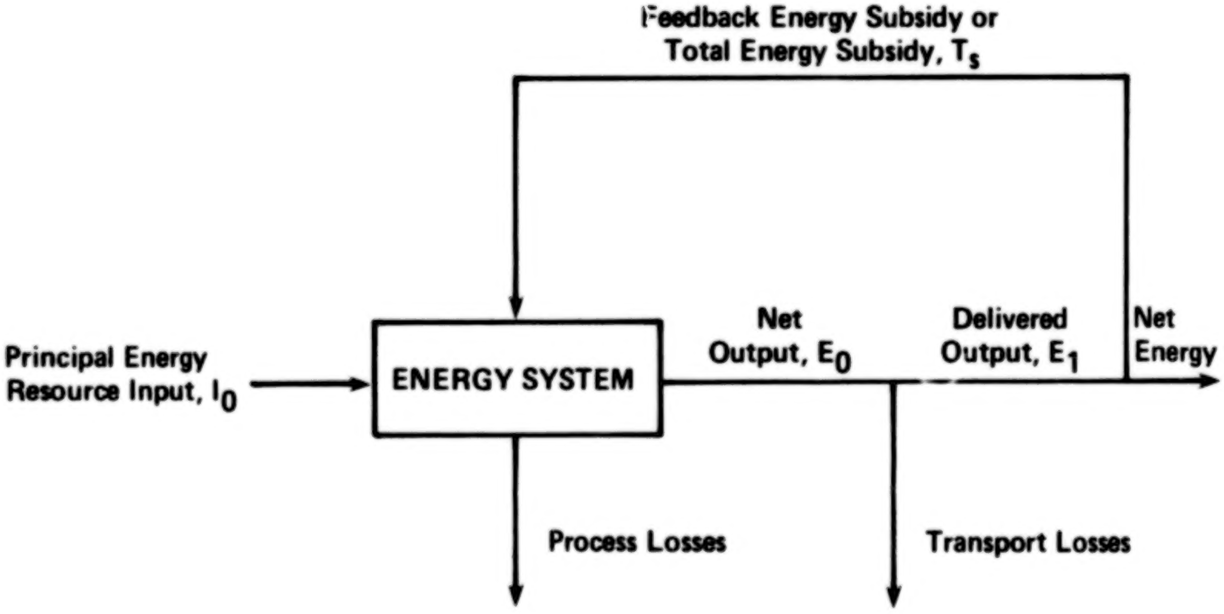
Feedback Energy Subsidy or
Total Energy Subsidy, T_s
Principal Energy
Resource Input, I_0
ENERGY SYSTEM
Net
Output, E_0
Delivered
Output, E_1
Net
Energy
Process Losses
Transport Losses

Figure 3.- Energy system with energy of a single form.

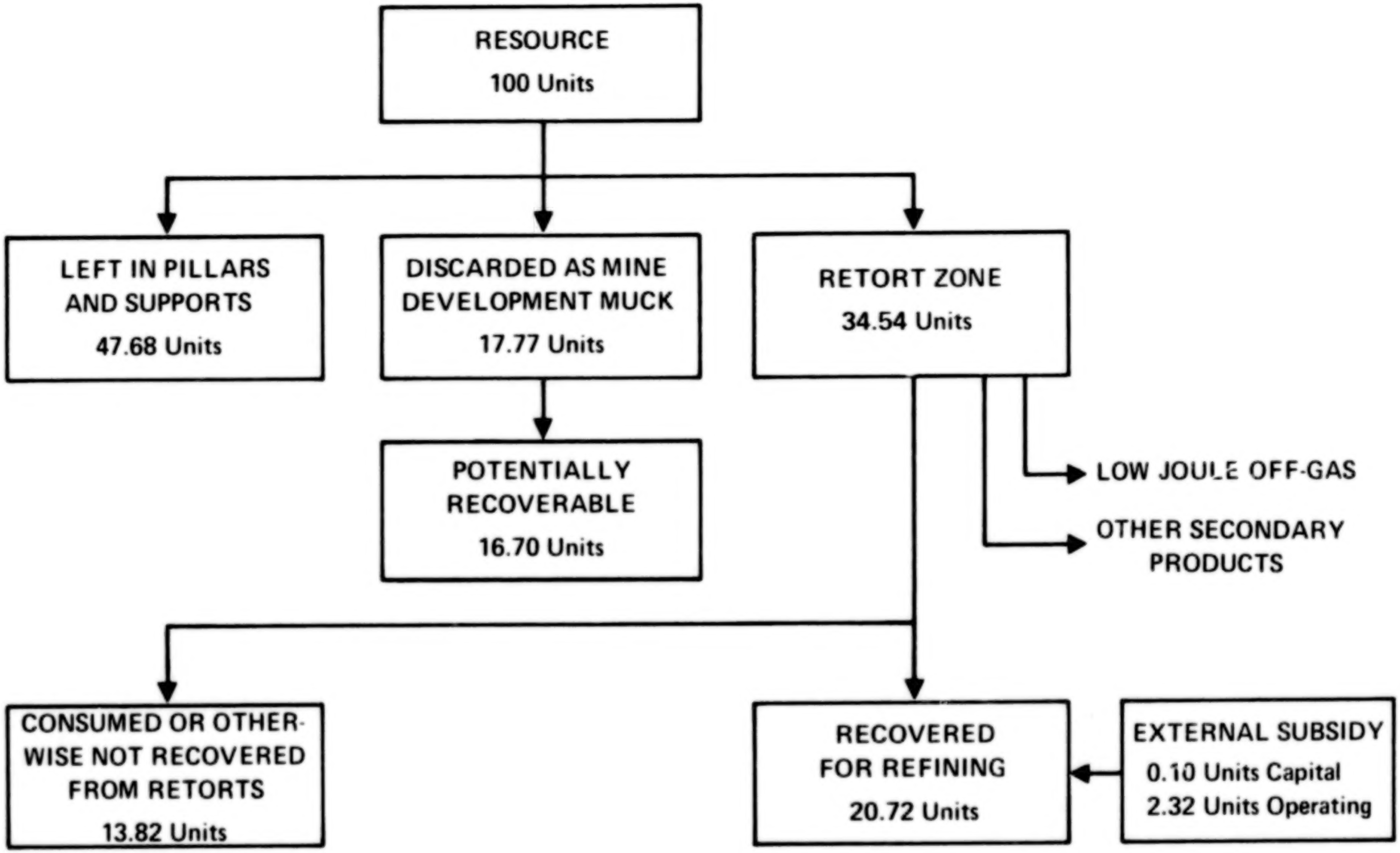
RESOURCE
100 Units
LEFT IN PILLARS AND SUPPORTS
47.68 Units
DISCARDED AS MINE DEVELOPMENT MUCK
17.77 Units
RETORT ZONE
34.54 Units
POTENTIALLY RECOVERABLE
16.70 Units
LOW JOULE OFF-GAS
OTHER SECONDARY PRODUCTS
CONSUMED OR OTHER-WISE NOT RECOVERED FROM RETORTS
13.82 Units
RECOVERED FOR REFINING
20.72 Units
EXTERNAL SUBSIDY
0.10 Units Capital
2.32 Units Operating

Figure 4.- Resource utilization for in situ oil shale processing.

EMERGING ENERGY ALTERNATIVES FOR THE SOUTHEASTERN STATES

PANEL DISCUSSION

MODERATOR: James Harris, Rockwell International Science Center

SUBSTITUTE MODERATOR: James Hutchby, NASA Langley Research Center

PANEL MEMBERS:
Donald E. Allen, U.S. Department of Energy
Warren D. Devine, Institute for Energy Analysis
James Dollard, U.S. Department of Energy
Robert P. Kennel, Ultrasystems, Inc.
A. Sidney Roberts, Jr., Old Dominion University

James Harris:

I would first like to thank the Symposium Committee for inviting me to be a participant in the symposium. I think it has been a very good program; the cross section of speakers has been outstanding and has given a good perspective on the energy situation. I would also like to make a few comments that really enforce what Don Allen talked about, in the sense of being part of the Technological Community that is working on trying to provide energy alternatives, and seeing that a basic change in the American public has to occur. We just are not going to be able to satisfy that unquenchable demand for energy. To give you some idea, let us look at the photovoltaic area which I am most familiar with. Warren (Devine) mentioned payback periods being very long possibly for photovoltaics. I think this is going to be true of many of the alternative energy sources. The payback period is going to be longer than it has been for oil and other fuels, and we will be unable to increase our energy capacity as rapidly. I am also very concerned to see that surveys indicate 40% of the American public does not believe there exists an energy problem. Don (Allen) I see the conservation problem really as an educational problem and not as a technological problem, or even as a political problem. Maybe you could address that question? Are there technological problems still to be solved, if not, what kind of political and educational possibilities do you see?

Donald Allen:

Well, I ask that question everywhere I go. What can we do to get the word across to the American public? I might turn that around and ask you ladies and gentlemen, what do we do? It's sort of a tough one to handle. The grant programs that I mentioned, one of the State Energy Conservation Programs, has five mandatory elements which will require the states, if they want federal grant money, to do certain things. In another conservation program we have a mandatory element which calls for school programs, educational programs on energy problems and conservation right down into the lower levels in the elementary schools. I think this is a step in the right direction.

If we can get the children, your children and mine, educated in terms of conserving energy and doing other good things, we will be able to stretch out our energy supplies a little further than we would otherwise. But, to get the word across to all the people is very difficult. Dr. J. Harris said 40% do not believe that there is an energy problem, and 50% of the people are not aware we import oil. And yet, the papers are full of news about this, which tells me something -- that not all the people read the papers. So its a tough nut to crack. How do we get the word across to everyone on conservation.

James Harris:

I also see it as an individual problem. Each person must contribute by being part of the solution and not part of the problem. There is not going to be someone in the Capital Government or in the Technological Community who will suddenly drop a solution.

Donald Allen:

One of our problems, of course, is that the States all vary in their energy rules and regulations. Many states do not have thermal and lighting efficiency standards in new buildings or in renovated buildings. So, the quicker the States get going on establishing energy laws, standards, and codes, the sooner we will see an impact in energy conservation.

James Harris:

A second question I had relative to the Southeast is what beyond conservation would be the next technology that is going to affect the energy picture relative to either possible wood systems, commercial heating and cooling, and industrial process heat? Jim (Dollard), would you care to venture some opinions?

James Dollard:

Yes, I sincerely believe it would be a combination of all of the (above) technologies along with conservation. On the basis of what I have seen, no single technology could reach 10% of our energy load in terms of fuel displacement. But, if we look at these technologies collectively, (and we are talking about ten to twelve different technologies), if each contributes 5% you will get a large percentage.

James Harris:

I would now like to have an open session questions from the floor. Would the questionnaire please identify themselves.

QUESTION (James Hutchby):

As a follow-up of your question, what would be the next source of fuel for the Southeastern States, do you have any idea as to what is the distribution of energy requirements in the Southeastern States, relative to electric energy, low temperature process heat, or high temperature process heat, that might give us an idea as to which of the processes are more amenable to our needs in these States?

James Dollard:

One figure, which is in the paper I gave, is that the Southeastern States are the highest per capita users of electric kilowatt hours. That might be a signal that what we are looking for is more electric power generation in the Southeast. In fact, at least in our service area, our utility (VEPCO) is seeking to replace fossil fuel burning boilers with light water nuclear fired boilers in order to generate more of the needed kilowatt hours. So, certainly, over the next ten years or so, we ought to see a movement that way. As far as some of the alternate conversion schemes are concerned, their impact in the Southeast is going to be miniscule. But, things are going to happen, like there are going to be 2 MW wind machines out here at Boone, and there will be other nuclear power stations. There is going to be a transition that Don Schuler introduced to us, where all the various concepts are going to be implemented, hopefully through commercial demonstrations, within the next ten or twenty years. But the impact specifically in our region and on the overall energy budget is going to be small in that period of time.

Robert Kennel:

There is a rule of three's with respect to the amount of energy used in the State between industrial processes and people processes. If I remember correctly it is something like 1/3 of the energy consumption is in industrial processes, 1/3 in home uses, and 1/3 in transportation. Although these numbers may be wrong, they are large fractions in easily identified blocks. One of the things that always strikes me, as I see it, is that there are only two things that ever impact the American public. Now, I don't claim to be a deep thinker on the subject of Energy philosophy, I claim to be a consumer and a guy that pays money out of my pocketbook, and as a businessman in anything I try to espouse or sell, I like to subject myself to the consumer view of the product. When we talk about conservation, selling conservation to the American public, we are talking about individuals like you and me turning off lights, buying small cars. We are talking about actions that are very much personal decisions and in this regard I only see two things that ever bring us to these personal decisions: (1) a true crisis, and the closest we have come to it is the wait at the gas pumps, (I don't really think that the American public really knew that there was a bad fire in Saudia Arabia and things were almost knocked out), and (2) high prices, whether it be in the home heating bill last month, or the continued rising of gasoline prices.

Sidney Roberts:

Are you saying that we would not have conservation unless those things happen?

Robert Kennel:

I frankly believe that energy education in the high schools, I mean in the elementary schools, is never going to truly make the case. We can't have another Smokey the Bear come along and make the case to the American public. I think it is going to come on economic terms and on hard out-of-work, no-gas type crisis, visible crisis. Now, everything we have talked about in terms of new energy sources today have all been on a very microscopic level. Anytime you say the word quad, by definition, to me, it is not real world. One of the things I have been doing recently is talking about wood energy. There is something enlightening to me about wood energy in that it sounds to most people just as esoteric as some of these energy sources, except that it is in a visible position on a day to day basis. Speaking as a businessman, I am faced daily with some very real payback demands in the market place. I am out there trying to sell wood energy to a plant manager who immediatly puts it in absolute dollars and cents. His payback is not in terms of energy payback, his payback is "can I get my money back in a year or a year and a half." I know that wood energy as a case in point is something new to most people, and most textile plants have not burnt, or utilized wood energy. You propose using wood energy to them and they apply dollar and cents tests to it. In the case of other energy alternatives, stringent payback conditions demand another five or ten years fuel supply and therefore force a different method of thinking. I don't know how to force the issue ten years ahead of time. It seems to me the same kind of question as how can I get my wife to turn off the lights?

QUESTION (John Cape):

Somewhere along that line I would like to ask the people that are here from DOE to explain to me the market-pull concept. That is, what is the likelihood that the efforts of the Department of Energy would result in industry putting their own funds into the development of technology. What are their problems?

Don Allen:

When you start talking about coal gasification and coal liquifaction, and other things with coal, we are talking about very large sums of money. The Industry needs some feed money, I suspect, from the Government. The question is how much money and how fast. There is a coal gasification demonstration plant being built right now in Kentucky. We will know more, shortly, how that process is going to work. That demonstration plant is being built entirely with Federal money. There is an effort right now to develop a consortium of industry and government to get into both coal liquifaction and gasification. They are still in the talking states because of the amount of money involved, and also because the companies want some reassurance on what future government policies are going to be, and I can understand that. It is rather tough when they don't know the rate of return they are going to be permitted to obtain from their investment into these types of processes. They are very reluctant to invest millions of dollars even though the Federal Government may match their money. However, some very good efforts are underway right now. Jack O'Leary, for example, the Deputy of DOE is in the process right now to get a group of industrial people together on the gasification and the liquifaction processes. We have got the coal, we know that. We have years and years of coal. The question is how best do you utilize it and how fast can we get at it.

James Dollard:

Let me add a couple of remarks concerning a couple of the other technologies. The market-pull concept I think is used also in the distributed technologies. There is a bill in front of Congress to put about 100 million dollars into buys for Government use. Now, that will not be economical, from the standpoint that it will not offset costs the Government would otherwise incur. The hope is that it will put two or three or four or five people into the business of high rate manufacture of photovoltaics so that they then become competitive in the open market place and can sell to the consumer. The same concept is being used to a lesser extent in the heating and cooling program. In our heating and cooling program we are sponsoring grants, primarily cost-shared, and we test the market place by what that cost share is. Right now, it is running well under 50% (that is, the projects we are now sponsoring are paid for more than 50% by the user). Quite frankly, I do not know if I would do business with the Government with much less margin than that. So, we assume that this is close to being competitive and that is borne out by the statistics which say that for every project start we sponsor, there has been about eight starts sponsored by industry. So, I think that the market-pull concept works. It is being carried out also in the Federal Building Program, which is also part of the NEA. If that passes, the Government will make a mandate that its buildings be retrofitted with heating systems just to make the market pull.

QUESTION (Winser Alexander):

What is being done by the Federal Government to encourage changes in the building codes to allow the installation of solar equipment, and also to encourage passive-type systems of conservation?

Don Allen:

There are several things. The Energy Conservation Plan that most of the states have contains mandatory elements the Federal Government has placed upon the states, one being thermal efficiency standards. In order for them to get money next year for example, they have to enact legislation this year in order to receive funding to continue their programs into the future. The President's energy bill tried to come up with utility rate reforms which in essence would require the states to do certain things on utility rates. For example, it would require the utilities to stop giving the cheapest rates to the largest users. As an example of the policies in the energy issue, the House of Representatives saw fit not to take the stand and they took the meat right out of that particular portion of the plan. Now the agreement between the conference committees is that the States will have two years to take a look at the situation. I only use one example, but this is part of the problem. It is partly political. There are factions at work on Capital Hill who represent industries that are going to be impacted.

ADDITIONAL COMMENTS FROM THE FLOOR:

Additional comments on what the Federal Government is doing on construction of buildings is from the State's Rights standpoint. They are not about to touch things like the local codes, primarily local building codes. However there is an executive order 11032, July of 1977, which requires any new construction to be at least 45% more energy efficient on a per square foot basis, and there is something set up in the Executive Order that impounds at least military construction, if not GSA construction in proceeding with the building unless the architect demonstrates he has incorporated energy saving techniques and devices.

Don Allen:

I must add, however, that many states are taking action in this direction. Florida, for example, has some recently enacted laws on the books that require construction of new buildings with certain insulation standards, and so forth. North Carolina also has some similar laws. Georgia this year passed a law which requires the establishment of such standards within three months of enactment of the law, and that is well on its way. Certain states are jumping on the bandwagon and changing their laws to help this particular area, but not all of them. Some of the states are doing this because of the threat of withdrawal of funds for their programs. That is not a very good way to say it, but let's face it, some states are doing it because of the threat. Some states are passing these laws because they recognize they have got to do it in the long run in order to conserve energy.

QUESTION (Polly Harris):

What is the reason for the Southeast having the highest per capita usage of electricity?

Sidney Roberts:

I can't tell you the exact answer to your question. It does have to do with the industrial mix and regional diversification. It also has to do with the way people use energy in industry, homes, and in buildings. Perhaps some of the other panel members may have some comments.

Don Allen:

There is another basic answer to why we use so much electricity. The Southeastern States really don't have any natural gas and oil to speak of. We are importers of almost all of our energy. Even the natural gas comes from Texas, Louisiana, and Oklahoma and the same with oil. We are very energy poor except in the terms of coal. Factories and homes that might use natural gas or oil are using electricity instead. It is also interesting to note how electricity is generated within the Southeastern States. The state of Florida relies almost entirely (about 80%) on imported oil from Venezuela, an OPEC country, whereas Georgia, right next to it lies just in the opposite vein and gets 80% of its electricity needs from coal. So, there is large variation from state to state. I know South Carolina is heavily dependent on nuclear energy and so is North Carolina. But one of the very basic answers to the question is that we do not have any oil or natural gas in the Southeastern States so we need some other form of power which happens to be electricity, to a large extent.

James Harris:

Warren (Devine), do you have anything to add?

Warren Devine:

Yes, I think you have brought up a very fundamental question, especially in the long run. Are we going to be a very centralized society from the standpoint of energy supply, or are we going to be more decentralized? Electricity, because of its centrally generated nature, at least at present, would lead us in the direction of centralization and certainly, if we continue along the nuclear energy path, it might even seem that we would go much, much further toward centralization. There are some studies being done that say if we are going to have an all nuclear economy or an all electric economy, the reactors ought to be placed in energy parks and maybe there would be ten or twenty or perhaps even fewer of these energy parks. That's as far away from where we are today in the direction of centralization as some of the arguments of Amory Lovitz. He thinks we should go the other way; have a very highly decentralized society and match the quality of energy required to that provided very carefully. I think this is a fundamental point and technically, probably both are possible. Economically, maybe there is a greater difference But it's probably more of a social or political question.

QUESTION (Conrad Dalman):

The conference has dealt with emerging energy technologies. Now the Arthur D. Little Company has proposed a rather speculative idea. That is, to take solar energy from out of space, convert it to microwave, radiate it to earth and convert this radiation back to DC current. Would the panel like to comment on that? I realize it is not on emerging technology, but I am interested to hear your comments.

James Harris:

I will make a few comments. First, Rockwell International is carrying out one of the studies for NASA on the Satellite Power Systems, and second, I have been involved in the photovoltaic aspect of the project. There are two concepts that are being looked at. One uses the Brayton Thermocycle System, the other is photovoltaic. There are some immense problems associated with the system as you might imagine. Building a platform up in space that covers a 15 x 30 km area is a massive undertaking. The main advantages that it has from a solar standpoint are (a) continuous solar radiation (not subject to weather conditions) and (b) considerably brighter sun. On the other hand, there are some immense technological problems in terms of converting. For example, they are talking about having solar panels operating at about 30 to 50 thousand volts. If you are a solar man that sends shudders up and down your spine.

James Dollard:

I might comment that the Department of Energy has done some studies on the environmental impact of the (above) concept and there are a couple of pretty serious concerns which may or may not turn out to be true barriers.

One of them is the holes in the atmosphere punched by the boosters that are launched, (million pound boosters launched one a day). The second concern is the down radar light (microwave beam) interfering with the upper atmosphere and leading to somewhat the same conditions as those caused by the SST. I don't know if these are real but they are of great concern to a lot of people.

QUESTION (Carolina Power & Light)
Is the DOE still pursuing investigations on the feasibility of a hydrogen economy?

Don Allen:
They were and I suspect they still are, but I don't have the details on that. I went to an OTEC meeting in Miami not too long ago, and that subject came up. I got the gist of the reply to a similar question that hydrogen did not look as favorable as they thought at first. So, I really don't know what the status is. Perhaps one of the other panel members could answer this.

Warren Devine:
I specifically heard a couple of numbers on cost. One paper I heard discussed the cost of producing hydrogen from wind electricity, and the cost for the hydrogen was very high, about twenty times that of natural gas, but it was competitive with other ways of getting hydrogen in this particular region (Riverside, California). They wanted hydrogen-powered buses and the study concluded, yes, we could make hydrogen from wind machines here and the cost would be about the same as getting hydrogen from other sources. But, it's still twenty times more than natural gas.

QUESTION (Dianne Allison):
What effect does the thinning out of trees have on the enviroment? If one did an intensive thinning out of trees, what long range effect would it have on the ecological balance of the forest.

Robert Kennel:
I don't pretend to be a forester, but I have talked to a number of people who are primarily working through the Forestry Department. Dean Eric Elwood of North Carolina State University, Ralph Winkworth, a state forester, and Dr. Tom Ripley with the Tennessee Valley Authority, the forester for TVA, to name a few. I have not run into anyone yet in the forestry area that has not said that a thinning or even a clear cutting, which sounds very harsh or reforestation with a better breed of trees has anything other than the very best benefits for the forest. Governor Millikan of Michigan was talking to the Audubon Society last November about some extensive study in Michigan on some type of bird they were afraid was nearing extinction. A surprising result in this study showed that this particular bird not only survived but thrived under the thinning concept. Now there is no simple way to rap it all up, except to say that all the experts I have ever talked to or read about in the forestry and conservation magazines say that an intensive management of the forest in the form like I was talking about is very good for the forest. They have been

doing this for two hundred years in the Black Forest in Germany and it is one of the most beautiful and parklike forests in the world. It has come from intensive management and cuttings, except they did it by hand which is not very efficient. We are talking about doing it by machine.

QUESTION (James Harris):

What provisions are being made in the legislation that is pending for tax incentives for energy-saving installations? Last night Jim (Dollard) made an interesting statement that Solar energy right now is hurting because everybody is waiting for the tax law to be straightened out. They should either give it to us, tell us the truth but just don't promise. Don, do you know the status of the legislation?

Don Allen:

The status of the legislation is that the Senate committees have elected not to get into the tax situation until the natural gas pricing situation is resolved. What happens in the natural gas pricing will affect the tax structure and so, until we know how they are going to vote on the natural gas pricing, and then, of course on the crude oil equalization tax, what emerges remains anybody's guess. I feel reasonably sure there will be incentives. Industry right now has, through previous laws, a ten percent tax deduction. The original proposal was to add another 10%, if my memory serves me correctly on top of the first 10% for a maximum write off of 20%. But how it will be in final version, we will just have to wait and see.

QUESTION (James Harris):

Is the situation for individual tax credit still being retroactive to April 1977?

Don Allen:

If you insulated your home you could get a maximum tax credit of $400.00 retroactive to April 20, 1977. In other words, if you put any type of insulation in your home such as storm doors you could claim it last year. Now, we have gone past that for the end of the year, and income taxes are supposed to be going in. However, there is a provision that will do one of two things. Either a form will be filled out if you did insulate your home last year, which could be sent to the Internal Revenue Service and get a separate check, or they (the Internal Revenue) will make an entry on next year's income tax form to cover the situation. I feel almost 99% sure that you will get credit retroactive to April 20. The question is the type of form you will use to get your tax credit. Since I put storm windows on my house, I am also interested.

QUESTION (Karlene Stefanakos):

In view of all that has been said here today concerning a very real energy crisis, and relating this to the Rockefeller Report which studied Western Government's behavorial patterns in facing this inevitable crisis (politically and economically), do you as panel members agree with their conclusion that world war in the 1980's is a very real possibility?

James Harris:

I will offer my opinion. I am very seriously concerned, because when you hear things like 50% of the people do not know we import oil, I think there will probably have to be some more occurrences like the waits for gasoline in 1973. It is my opinion that people are going to have to be reminded or hit over the head a few times before that message comes through.

Robert Kennel:

I would like to add a peripheral remark to that. It seems to me that every week around the land there are energy conferences similar to this, but there are very few conferences in which we find significant political leaders. We have a panel here of people who form academic, industry, government executive branches or agencies, but we don't have a Senator, or even a North Carolina Senator sitting up here. Perhaps we need that person very badly and a number of them are needed to be invited, even if we have to pay their way, to come into these conferences to hear what we have heard today. We have to participate in the political process. It is up to the institutions who run these conferences to also bring in the political side of the issue.

QUESTION:

Do you feel that if the United States comes to terms with its energy crisis, that this will be enough of an impact to avoid a tragic collision over energy world-wide?

Don Allen:

Obviously, we cannot do it all ourselves, and we really should not. If we do reach production capacity, which we feel reasonably sure we will, in the 1980's then this will have a significant impact in the world energy situation. However, in cases like Japan and the nations of western Europe, all highly dependent upon imports, much more so than we in the United States, all of these nations are going to be competing price-wise or any other-wise for the oil that is available primarily from the OPEC countries. Something may have to give. Whether this situation does or does not lead to war, one can only guess. It has been known to happen in the past. But, we are working with other nations within the Department of Energy. We are members of committees, international committees, and we have people working with other nations on the energy problem. We also have agreements with other nations on energy supplies under emergency conditions.

Warren Devine:

I would like to offer another cataclysmic thought for those of you that don't like wars. No one has mentioned the possible detrimental effect of increased use of coal. There is a lot of research going on concerning possible climatic modifications due to carbon dioxide in the atmosphere. Certainly, the United States' emphasis on coal use, particularly in the National Energy Plan through 1985, isn't going to have much effect on atmospheric concentration of carbon dioxide. But, should we act in our usual role as the world leader and should other nations such as the Soviet Union and China and Poland use their coal resources to a great extent, it's conceivable that some time around the turn of the century we could begin to experience climatic changes. There's a lot of research going on and it is not really easy to tell yet whether this is a real possibility, but it can serve as a reminder other than a military one.

QUESTION:
How are we going to know how much progress we are making with respect to installation of solar equipment?

James Dollard:
This is a very good question. It is one of great concern to a lot of us in the solar energy division. In the area of home heating and cooling, the estimates may vary by a factor of five in the annual production of solar equipment within the U.S. We are currently working with organizations such as the Solar Energy Industries Association, trying to set up a mechanism or data base to get hard data on the amount of solar collectors that are installed. There's probably not a practical way, however, except by some kind of projections based upon weather data telling how much fuel it displaced or how many Btu's it generated. But, we feel we can in the next year or eighteen months get a data base going that will tell us how much equipment is being produced and how much is being installed. But, right now it is very, very difficult to find out.

James Hutchby:
Are there any additional questions from the audience?

QUESTION:
What is the energy payback on a standard nuclear power plant?

Warren Devine:
Other people at our institute analyzed about 10 or 12 different nuclear power plants including the standard boiling water reactor and light water reactors, and the payback period varied between three and ten years over a thirty year life time. For the standard ones, I think the numbers are like four to four and a half years.

James Hutchby:
Are there any additional questions? I think if there are no additional questions, we would like to thank each of the speakers for the very fine talks we had today. I would like to thank the members of the panel and the others for sticking out to the very bitter end (5:00 o'clock) and I will now turn the program over to Dr. Stefanakos. Do you have anything else that you would like to add.

Elias Stefanakos:
I would like to thank each one of you for attending and being patient and persistent throughout the Symposium. Thank you very much.

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